SECTION F - OUTLET STRUCTURES

Contents

Figures

SECTION F - OUTLET STRUCTURE

I. INTRODUCTION

Flow from the reservoir through the outlet conduit may be carried for some distance through an irrigation pipeline distribution system or discharged just beyond the toe of the embankment. In any event, water will emerge at relatively high velocity whether discharging submerged in a pool or freely into the air. Where it is to be carried in an earth channel, an outlet structure is required to dissipate or absorb excess energy. The flow should pass into the earth channel at non-erosive velocities for all stages of discharge to prevent undermining of the outlet.

Several types of outlet structures have been used successfully in Service work. Conditions under which each of four types should be used has been described in terms of hydraulic limitations and economics on Figure F-11.

The structure most subject to variation in cost due to site conditions is the cantilever outlet and its plunge pool. This is especially true if the pool requires armor plating. The other types compared are the PWD, Impact, and the SAF basins.

II. CANTILEVER OUTLET

The cantilever outlet is a low cost terminal structure that depends on turbulence in a plunge basin for energy dissipation. Its economy is most apparent in situations where the soil material in the downstream channel is erosion resistant. Its economy is also evident when rock is readily available and cheap and used as an armor plating of the plunge basin where the foundation material is less erosion resistant. Whether armor plating with rock or not, a preformed scour hole is recommended. If not preformed, the material scoured from the plunge basin will be deposited in the channel downstream forming an artificial barrier raising the tailwater level and possibly submerging the outlet to affect the hydraulics of the conduit system. It is important that the jet trajectory have some drop from the conduit to pool water surface for better energy dissipation within the pool.

A schematic diagram and nomenclature of the cantilever outlet and the stilling basin is given on Figure F-4. Design criteria for proportioning the basin is given in SCS Design Note No. 6. The value of p in Figure F-4 should be a minimum of one foot. For calculating quantities above the plane of the downstream channel invert, the following equation is given as supplementary to those of Design Note No. 6:

$$V = \frac{\pi y}{108} (32.65h^2 + 61ha_2 + 28.23a_2{}^2 + 26.165ya_2 + 28hy + 12y^2)$$

The nomenclature is that given on Figure F-4 except that y is the vertical distance to the upper level plane of excavation or riprap. The area of the downstream channel entrance is included in the volume and must be deducted from the rock quantities.

Information on structural details for the cantilever outlet is given in Figure F-5 through F-9. In all cases the bottom of the cantilever bent should extend to a level below that of the basin bottom, unless it rests on rock.

Use of the cantilever outlet should be restricted to sites where it is compatible with the surrounding improvements and piping is not a foundation problem.

On occasion a submerged outlet has been used; these should be limited in use to small outlets and low system heads. No design criteria is given here for the proportioning of this outlet type.

III. PWD BASIN

PWD is an abbreviation for Public Works Department. This basin is recommended for low head systems. A diagram of this structure and its proportions for various head-conduit diameter combinations is given in Figure F-1. For effective operation, this structure depends on the formation of a hydraulic jump for energy dissipation, consequently tailwater is an important consideration. Plate F-1 illustrates faulty operation as a result of inadequate tailwater. The crest of the outlet sill should be set at the same elevation as the invert of the conduit outlet. Flow velocities in the downstream channel should be in the subcritical velocity range with normal depth equal or greater than critical depth at the structure sill. Riprapping the bottom and sides of the channel for a distance of four conduit diameters downstream of the structure is recommended for shallow tailwater conditions. This will also provide transition protection when the channel is wider than the structure. Refer to Figure F-3 for rock riprap size.

A sample of a standard drawing for this type structure has been included in this section as Figure F-10.

PLATE F-1

IV. IMPACT BASIN

The impact basin is recommended for use with long duration flows and where the downstream water level will not meet the minimum tailwater requirements for the formation of a hydraulic jump. Entrance velocities should be restricted to less than 30 fps. Figure F-2 is a schematic diagram and a selection chart for various head-conduit size relations within the limits of the hydraulic capacity of this type of structure.

A short length of conduit leading directly into the impact basin should be level or set on a slight positive slope. During low flows, experience has shown the jet leaving a steeper conduit will miss the impact wall completely.

Impact basins should not be used with open top inlets where heavy or long debris can be expected unless an extensive trash rack is used.

Riprapping the bottom and sides of the downstream channel for a distance of four conduit diameters is recommended. Refer to Figure F-3 for riprap sizes.

For computing the hydraulics of a full flow conduit system using an impact basin, THE OUTLET WATER SURFACE SHOULD BE ASSUMED TO BE AT THE TOP OF THE BAFFLE WALL.

A sample of this structure has been included in the completed example in Section H as Figure H-5.

V. SAF BASIN

The St. Anthony Falls hydraulic laboratory developed an energy dissipating structure used extensively in the Service. This structure is known as the SAF basin. It is recommended for long duration flows, high entrance velocities and discharges in excess of 400 cfs. This structure has not been standardized because of the number of variables involved so that each installation is a separate design. NEH 14, "Chute Spillways", provides procedures for the hydraulic proportioning of the SAF basin.

The SAF basin depends on the hydraulic jump for energy dissipation. Unless tailwater satisfies the jump requirements over the major portion of the discharge range ineffective operation results. The ratio, TW/D_2, tailwater depth (TW) to depth required for the jump, (D_2), should be within the limits of 0.8 to 1.2 for the full range of discharge (see Plate F-2). However, for low discharge short duration flows the tailwater rating curve may exceed the TW/D_2 ratio of 1.2 without serious consequence.

Plate F-3 is an excellent illustration of malfunction in a SAF basin because of inadequate tailwater. Loss of a hydraulic control downstream or degradation of the channel is the usual cause of low tailwater. Because of low tailwater, the high velocity jet leaves the structure with little energy loss further aggravating the downstream scour problem.

Elevation of the SAF apron should be established by using the lowest roughness coefficient and a scoured grade line in the hydraulics of the downstream channel. Elevation of the top of the SAF sidewall should be checked using the highest roughness coefficient in the downstream hydraulics.

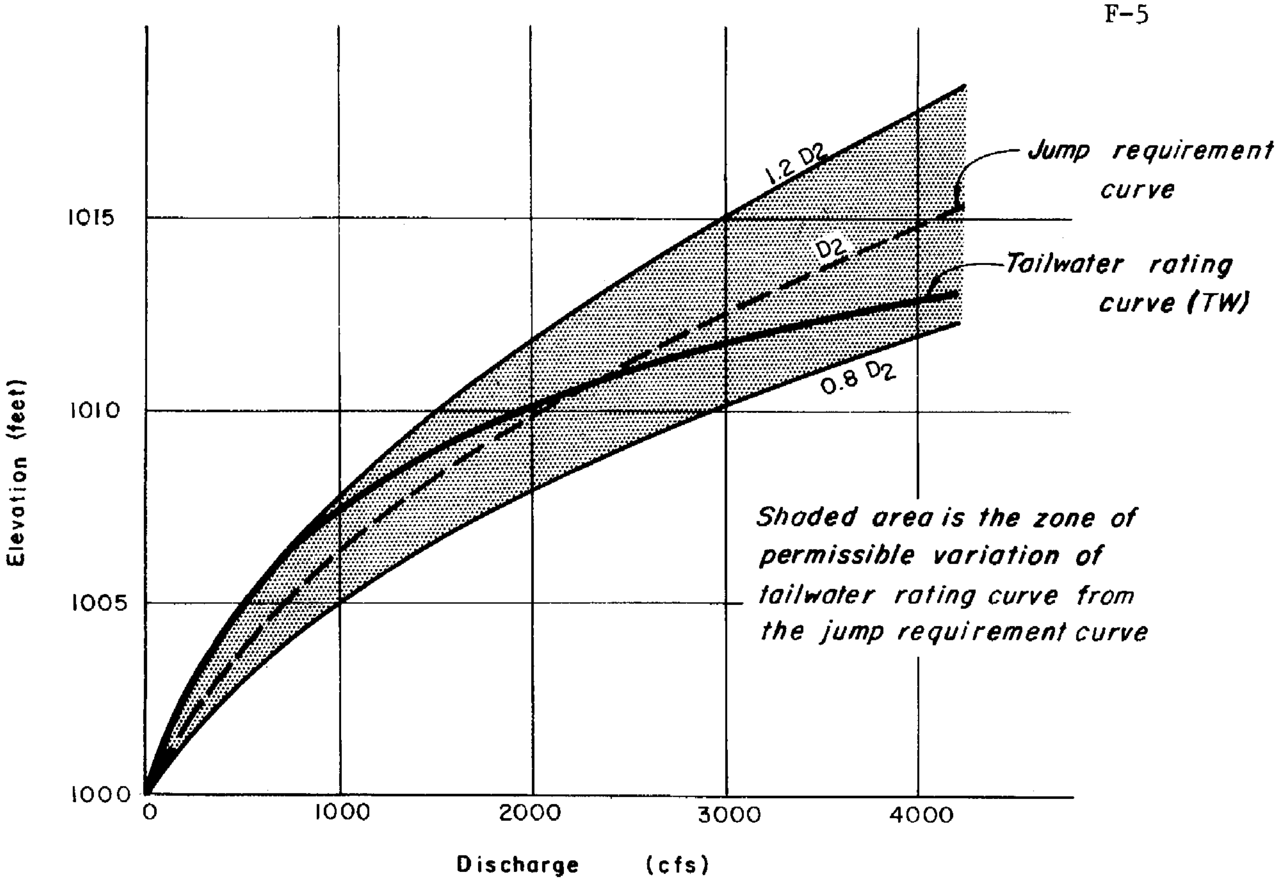


PLATE F-2

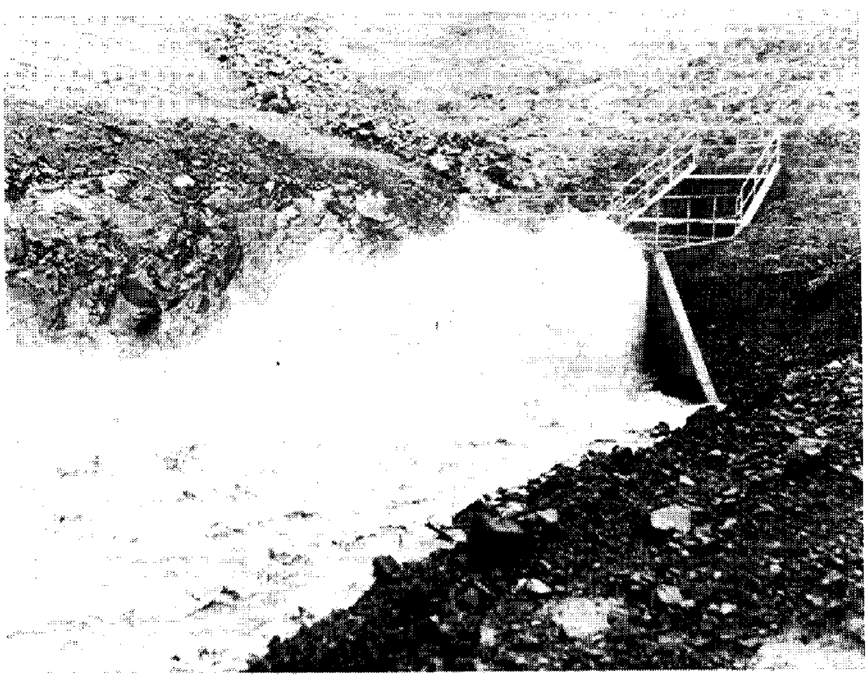


PLATE F-3

VI. OTHER OUTLETS

Several other types and variations of the above structures have been used in the past with success. These have been for special installations with limited application. Four deserving specific mention are the Manifold Outlet, Bianchi Bench, SCS Baffle, and the Submerged Outlet. No coverage of these structures is given here.

VII. OUTLET STRUCTURE SELECTION CHART

Figure F-11 is not intended as an all inclusive evaluation of outlets but rather as an aid to the less experienced in eliminating those choices between types of outlets hydraulically inadequate or economically undesirable for a given set of conditions.

This figure has been divided into two conditions:

Condition 1 - rock riprap is not required in cantilever outlet plunge basin, and

Condition 2 - rock riprap is required in cantilever outlet plunge basin.

Before using Figure F-11, the downstream channel conditions should be evaluated. If rock riprap is not required, Chart A in Condition 1 provides a choice between a cantilever outlet and a PWD basin. The PWD basin should be acceptable only if the tailwater requirement can be satisfied as described in the discussion of hydraulic jump (see Plate F-2). For conduit diameters to 30 inches the standard PWD structure is more economical. Above 30" conduit diameter, for low heads, a modified PWD standard structure is less expensive to construct. It is the designer's choice to use either the cantilever or to modify the standard PWD structure with the dimensions shown in Figure F-1.

If it has been determined that rock riprap is required downstream of the outlet structure, Condition 2 applies. When the unit cost ratio of reinforced concrete to rock riprap is less than 13, select a structure from Chart B. At this point the choice is between the SAF, Impact and PWD basins; the divisions between the three types is based on hydraulic limitations. Reference is made to Figure F-1 and F-2 for further size selection of the PWD or Impact basins.

However, if the unit cost ratio of reinforced concrete to rock riprap is greater than 13, the cost of a cantilever outlet with armor plated plunge pool should be compared with one of the three selected from Chart B.

VIII. EXAMPLE

By the time the system analysis has progressed to this point one of the conduits would have been selected for final design. To illustrate procedure a few comments are offered regarding those outlets suitable for conduits not used in the continuing example.

Ordinarily metal pipe (steel or CMP) would be cantilevered from a timber bent. Figure F-11 does not reflect the economy in initial construction for this combination of construction materials.

Both the 20" steel pipe and the 24" CMP would be cantilevered from a timber bent. Details for the bent can be found on Figure F-9. If the steel pipe is to be encased a R/C bent would be used and details from Figures F-6 through F-8 would be selected.

The example will be continued using the 21" R/C conduit.

A. Problem 1

Given: System head of 20 feet and 21" R/C conduit.

Determine: Type of outlet and construction drawing details.

Problem Analysis:

1. Evaluate need for armor plate in plunge pool.

2. Determine outlet type using Figure F-11.

3. Select appropriate structure size from Figure F-1, F-2, or F-4.

Solution: Referring to Figure F-11 with a head of 20 feet and a 21" conduit size, find choices:

1. If no armor plating is required, from Chart A select standard PWD basin size D. The drawing number can be found on Figure F-1.

2. If armor plating is required, from Chart B select impact basin and refer to Figure F-2 for size and standard drawing number.

B. Problem 2

Given: System head of 20 feet and 21" R/C conduit.

Determine: Construction cost and annual cost of alternate outlets and evaluate.

Problem Analysis:

1. Calculate construction costs for -

    a. Cantilever outlet unlined plunge pool
    b. Cantilever outlet with armored plunge pool
    c. PWD basin
    d. Impact basin

2. Calculate annual costs for each outlet.
3. Evaluate results.

Solution: In this comparison two alternate situations are considered:

1. Outlet control with the system head the same for all alternates.

2. Outlet elevation (downstream channel grade) the same for all alternatives.

These alternate conditions are presented to illustrate the need for having some idea of the outlet type during the initial hydraulic proportioning of the system.

For the construction cost comparisons the following unit prices will be used:

1. Excavation, cu yd	
Plunge basin and downstream channel	$0.50
Structure	1.00
2. Structure backfill, cu yd	1.00
3. Rock riprap (include filter) cu yd	7.50
4. Reinforced concrete, cu yd	100.00
5. R/C conduit, lin ft	20.00

For the annual cost comparison the following factors will be used:

1. Annual maintenance (% of construction cost)

a. Concrete structure	0.2
b. Earth channel	4.0
c. Rock Riprap	1.0
d. Earth backfill	1.0

2. Project life - 50 years (no salvage value)

3. Interest rate - 6% crf - 6% - 50 = 0.06344

Calculations supporting construction and annual costs for three different outlet types are presented on the following pages F-11 through F-20.

From the cost summaries listed on page F-20 it can be seen that cost economy favors the PWD outlet for a comparable head condition. For the comparable downstream channel elevation the cantilever outlet with earth plunge pool is less costly. Any significant change in the unit price of construction or maintenance costs could change the most economical choice. This statement is especially true if rock riprap was readily available and the cost of concrete was high.

The choice of outlet structure has been reduced to the cantilever outlet and PWD basin. Final selection will depend on careful evaluation of the downstream conditions. From the data given a PWD basin would be recommended.

For purposes of illustration an impact basin has been used in the continuing example and included in Section H, Drawing Layout and Summary.

The importance of economics in design cannot be underrated, but the designer must not lose sight of the possibility of changes in the physical and functional requirements of the site, and the added safety the more costly structure might provide, such as:

1. The impact basin has more positive energy dissipation.

2. If offsite conditions make the tailwater rating curve unreliable, the cantilever basin would be a better choice.

3. If the outlet design condition is not the maximum flow condition and there could be periods of greater discharge, the PWD basin would be more susceptible to damage.

4. Aesthetic values of one outlet as compared to another outlet are a consideration, especially in a more intensely developed area.

COMPUTATION SHEET
SCS-523 REV 5-58

STATE Far West		PROJECT Gated Outlet		
BY H.W.F.	DATE 1-7-67	CHECKED BY	DATE	JOB NO.
SUBJECT Cantilever Outlet				SHEET ___ OF ___

Given:

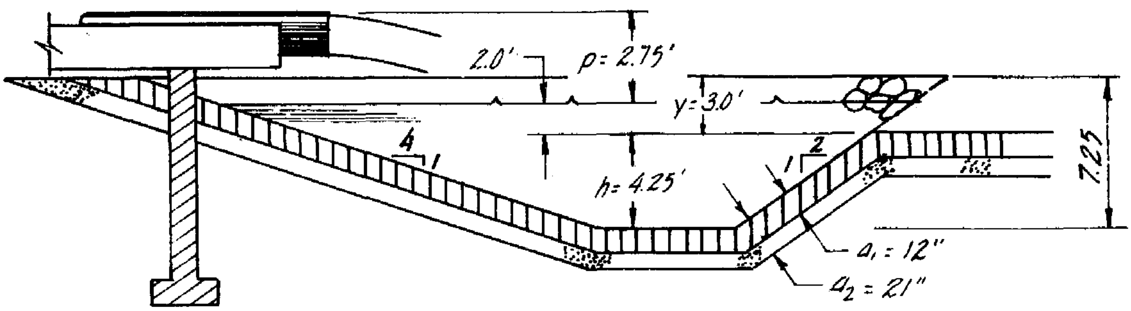
$Q = 48$ cfs
$D = 21'' = 1.75'$
$v = 19.9$ fps
$a_2 - a_1 = 9''$ filter thickness
$d_{50} = 4''$ available size
$y = 3.0'$
$m = 6.25'$
$p = 2.75'$

$a_1 = (2.5)4 = 10''$ use $12''$
$a_2 = 12 + 9 = 21''$

Refer to SCS Design Note 6 for nomenclature and procedure

Volume of excavation above invert

$$V_{ex} = \frac{\pi y}{108}\left[32.65h^2 + 61ha_2 + 28.23a_2^2 + 26.165ya_2 + 28hy + 12y^2\right]$$



Determine

1. Pool depth
2. Unlined pool volume (assuming $d_{50} = 4''$ as natural material in ds channel)
3. Lined pool volume
4. Construction cost estimate

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BY H.W.F.	DATE 1-7-67	CHECKED BY	DATE	JOB NO.
SUBJECT Cantilever Outlet				SHEET ___ OF ___

Solution

① Pool depth

$$\frac{Q}{D} = \frac{48}{1.75} = 27.4$$

ES 182 2/7 $\quad \frac{h}{D^{1/3}} = 3.5$

$$h = (1.75)^{1/3}\, 3.5 = 4.22 \quad \text{use } 4.25'$$

② Unlined pool volume

ES 182 4/7 $\quad$ Volume of excavation below invert

$h = 4.25 \quad a = 0 \quad = \quad 28.5\ yd^3$

Volume of excavation above invert

$h = 4.25 \quad y = 3.0$

$$Vol_{ex} = \frac{\pi(3)}{108}\left[32.65(4.25)^2 + 28(4.25)(3) + 12(3)^2\right] = 92\ yd^3$$

Total volume unlined pool $\quad 92 + 28 \quad = 120\ yd^3$

③ Lined pool volumes - excavation and rock riprap

Volume of excavation below invert

$h = 4.25 \quad a = 1.75 \quad = \quad 74\ yd^3$

Volume of rock below invert $\quad 74.0 - 28.5 \quad = \quad 45.5\ yd^3$

Volume of excavation above invert

$h = 4.25,\ y = 3,\ a = 1.75$

$$Vol_{ex} = \frac{3\pi}{108}\left[32.65(4.25)^2 + 61(4.25)(1.75) + 28.23(1.75)^2 + 26.165 \right.$$
$$\left. 3(1.75) + 28(4.25)(3) + 12(3)^2\right] = 151\ yd^3$$

Total vol exc. $= \quad 151 + 74 = \quad 225\ yd^3$

Total vol rock $= \quad 225 - 120 = \quad 105\ yd^3$

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STATE Far West		PROJECT Gated Outlet		
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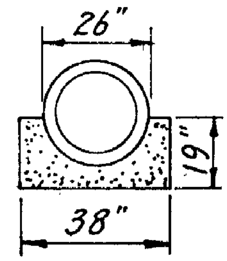
SUBJECT Cantilever Outlet				SHEET ___ OF ___

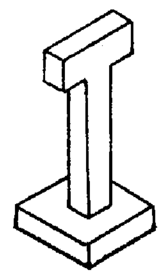
21" + 2.5" + 2.5" = 26"



④ Cost construction estimate

Cradle 0.137 cu yd/ft (Table J-E4)
14' (0.137) = 1.92 yd^3
Bent (Fig F-5) = 0.95 yd^3

Σ Concrete Vol = 2.87 yd^3



Unlined basin excavation	120 yd^3 @ \$0.50	=	\$60.00
Armored basin excavation	225 yd^3 @ \$0.50	=	\$112.00
Rock riprap	105 yd^3 @ \$7.50	=	\$787.50

Structure excav. bent
Assume 5 x 5 x 11 pit = 275 ft^3
$\frac{275}{27}$ = 10.2 yd^3 @ \$1.00 — \$10.20

Structure backfill
Structure excav. less structure concrete
10.2 - 0.95 ≅ 9.25 @ \$1.00 — \$9.25

Concrete cost
Cradle and bent 2.87 yd^3 @ \$100.00 — \$287.00

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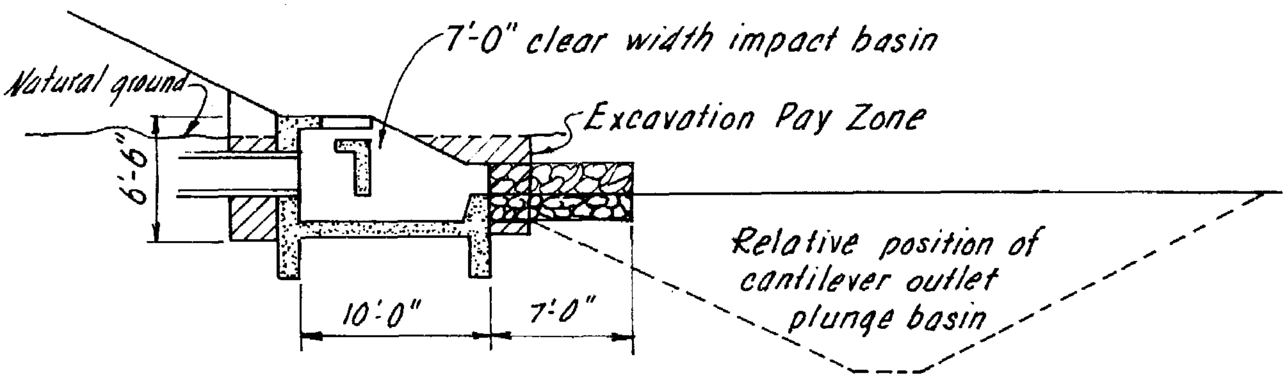
STATE Far West		PROJECT Gated Outlet		
BY H.W.F.	DATE 1-7-67	CHECKED BY	DATE	JOB NO.
SUBJECT Impact Basin				SHEET ___ OF ___

Cost Estimate

Given: Q = 40 cfs

Find: Structure width = 7'-0"
Std. Drwg. No. ES 4070-040 } Figure F-2



Volume Structure Excavation

Assume vertical payline 2'-0" clear of structure average 4.5' deep

$$\left[\frac{(8.7+4)(10+4)}{27}\right] 4.5 = 29.6 \text{ cu yd}$$

Cost of Structure Excavation

29.6 @ $1.00 — $ 29.60

Volume Concrete 8.0 cu yd (Est.)

Cost of Concrete 8.0 @ $100.00 — $800.00

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SCS-523 REV 5-58

STATE Far West		PROJECT Gated Outlet		
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SUBJECT Impact Basin				SHEET ___ OF ___

Cost Estimate (cont.)

Volume of rock

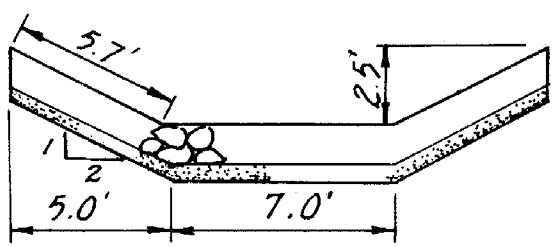
$H = 20'$ $d = 21''$

Rock size $D_{50} = 5''$

Layer thickness $3D_{50} = 15''$ — Figure F-3

Filter $D_{50} = 5''$

Length of rock protection (4D) use 7'-0"



$2(5.7) + 7 = 18.4'$

$$\frac{(18.4)(7)\frac{20}{12}}{27} = 8.1 \text{ cu yd}$$

Volume of excavation

$$\frac{[(5.9)(5.0) + (4.2)(7.0)]\,7}{27} = 15.3 \text{ cu yd}$$

Cost of excavation

(15.3)(.50) — \$ 7.65

Cost of rock
(8.1)(7.50) — \$ 60.75

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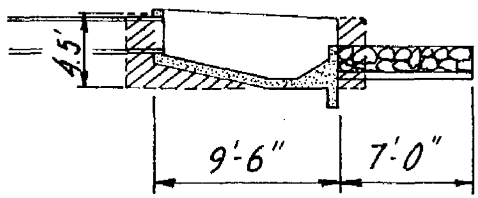
STATE Far West		PROJECT Gated Outlet		
BY H.W.F.	DATE 1-7-67	CHECKED BY	DATE	JOB NO.
SUBJECT PWD Basin				SHEET ___ OF ___

Cost Estimate

Given: $Q = 40$ cfs

PWD Basin Structure size D

Find: Cost Estimate



Volume of Structure Excavation

Assume vertical payline 2.0' clear of structure average 4.5' deep

front width = 8.25 + 2(0.75) = 9.75'

rear width = 2.42 + 2(0.75) = 3.92

$$\left[\frac{\left(\frac{9.75+3.92}{2}+4\right)(9.5+4)(4.5)}{27}\right] = 24.4 \text{ cu yds}$$

Cost of Structure Excavation

24.4 @ $100.00 — $24.40

Volume of Concrete 3.6 cu yds

Cost of concrete @ $100.00 — $360.00

Structure Backfill

$$\text{volume} = \left(\frac{8+10+10}{27}\right)(2)(4.5) = 9.3 \text{ cu yds}$$

cost of structural backfill — $9.30

COMPUTATION SHEET
SCS-523 REV 5-58

STATE Far West		PROJECT Gated Outlet		
BY H.W.F.	DATE 1-7-67	CHECKED BY	DATE	JOB NO.
SUBJECT PWD Basin				SHEET ___ OF ___

Cost Estimate (cont.)

Volume of Rock

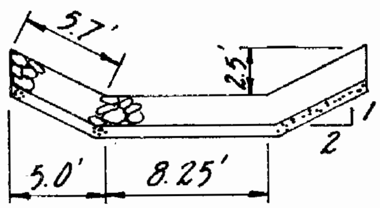
$H = 20'$ $d = 21''$

Rock size $d_{50} = 5''$

Layer thickness $= 3D_{50} = 15$

Filter $D_{50} = 5''$

Length of rock protection $= (4D) = 7.0$ ft



$2(5.7) + 8.25 = 19.65$

$$\frac{(19.65)\,7\left(\frac{20}{12}\right)}{27} = 8.5 \text{ cu yds}$$

Volume of Excavation

$$\left[\frac{(5.9)(5.0) + 4.2\,(8.25)}{27}\right]7 = 16.6 \text{ cu yds}$$

Cost of Excavation
$= 16.6\ (0.50)$ — \$8.30

Cost of Rock
$= 8.5\ (7.50)$ — \$63.75

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STATE Far West		PROJECT Gated Outlet		
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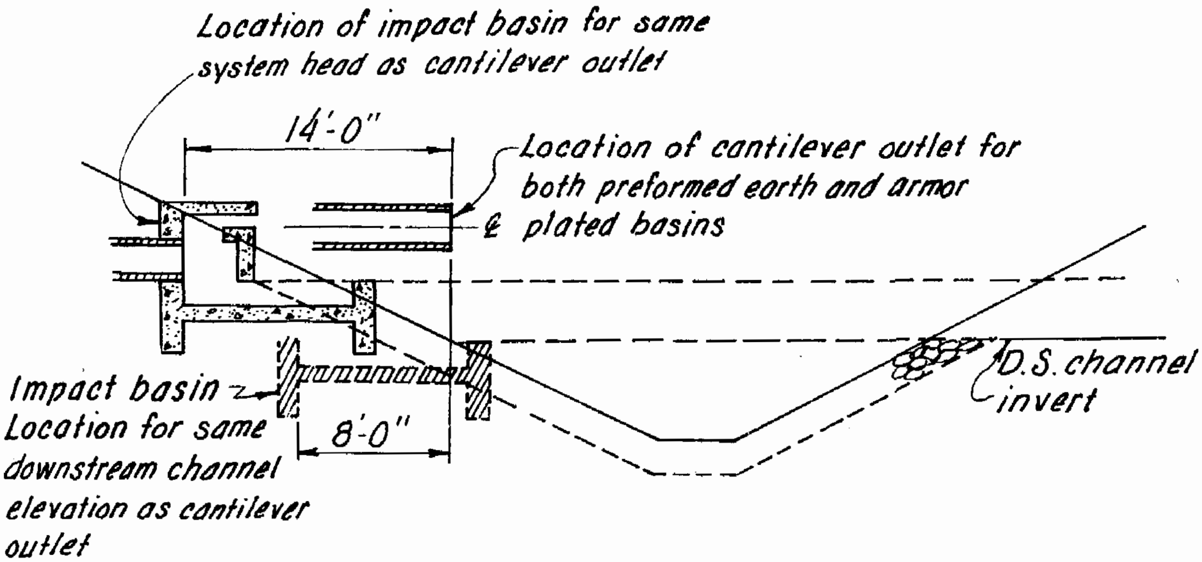
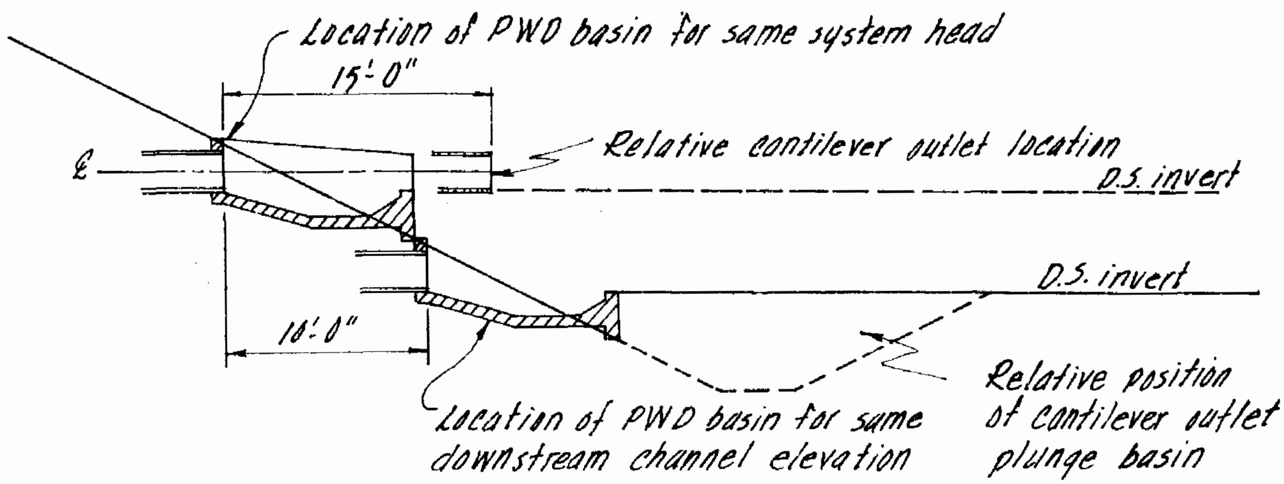
SUBJECT Alternate Comparison				SHEET ___ OF ___

Relative Location of Alternate Outlets



Relative Location of Alternate Outlet



COMPUTATION SHEET
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STATE *Far West*		PROJECT		
BY *H.W.F.*	DATE *1-7-67*	CHECKED BY	DATE	JOB NO.
SUBJECT *Alternate Comparison*				SHEET ____ OF ____

Annual Cost[1]

1. Cantilever Outlet - earth pool (comparable D.S. elevation or comparable system head)

a.	Annual cost conc. maint. = (95+192) 0.002	0.57
b.	Annual cost earth maint. = (60.00) 0.04 + 10.20 (0.01)	2.50
c.	Capital recovery = 0.06344 (646.70)	41.03
	TOTAL ANNUAL COST	$44.10

2. Cantilever Outlet - armor plate pool (comparable D.S. elevation or comparable system head)

a.	Annual cost conc. maint. = (95+192) 0.002	0.57
b.	Annual cost rock riprap maint. = (787.50) 0.01	7.88
c.	Capital recovery = 0.06344 (1486.90)	94.33
	TOTAL ANNUAL COST	$102.78

3. Impact Basin - comparable D.S. elevation

a.	Annual cost conc. maint. = (881.80) 0.002	1.77
b.	Annual cost rock riprap maint. = (60.75) 0.01	0.61
c.	Capital recovery = 0.06344 (1110.30)	70.44
	TOTAL ANNUAL COST	$72.82

4. PWD Basin - comparable D.S. elevation

a.	Annual cost conc. maint. = (483.00) 0.002	0.97
b.	Annual cost rock riprap. maint. = (63.75) 0.01	0.64
c.	Capital recovery = 0.06344 (769.05)	48.78
	TOTAL ANNUAL COST	$50.39

5. Impact Basin

a.	Annual cost conc. maint. = (800.00) 0.002	1.60
b.	Annual cost rock riprap maint. = (60.75) 0.01	0.61
c.	Capital recovery = 0.06344 (908.50)	57.63
	TOTAL ANNUAL COST	$59.84

6. PWD Basin - comparable system head

a.	Annual cost conc. maint. = (360) 0.002	0.72
b.	Annual cost rock riprap maint. = (63.75) 0.01	0.64
c.	Capital recovery = 0.06344 (432.05)	27.41
	TOTAL ANNUAL COST	$28.77

[1] R/W not included

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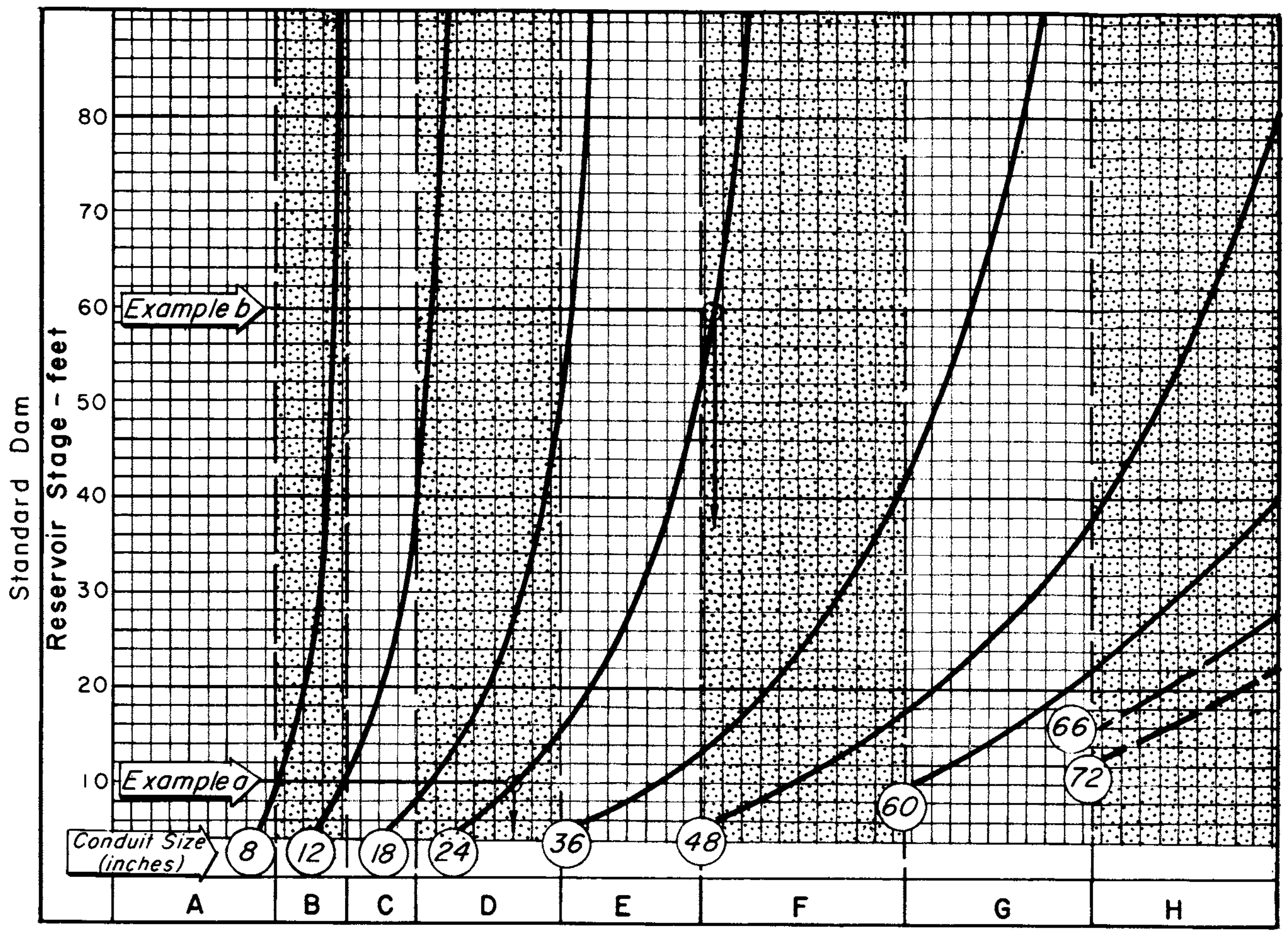
STATE Far West		PROJECT Gated Outlet	
BY H.W.F.	DATE 1-7-67	CHECKED BY	DATE	JOB NO.
SUBJECT Alternate Comparison			SHEET ____ OF ____

Construction Cost Summary

Comparable Head	Cantilever Outlet		Impact Basin	PWD Basin
	Earth Pool	Armor Plated Pool		
1. Earthwork				
Pool Excavation	60.00	112.50	7.65	8.30
Structural Excavation	10.20	10.40	29.60	24.40
Structural Backfill	9.50	9.50	10.50	9.30
2. Reinf. Concrete				
Bent	95.00	95.00	—	—
Cradle	192.00	192.00	—	-13.70
Impact Basin	—	—	800.00	—
PWD Basin	—	—	—	360.00
3. Rock Riprap	—	787.50	60.75	63.75
4. Conduit	280.00	280.00	—	-20.00
Σ Construction Cost	$646.70	$1486.90	$908.50	$432.05
Comparable D.S. Elev.				
Δ Cradle	—	—	81.80	137.00
Δ Conduit	—	—	120.00	200.00
Σ Construction Cost	$646.40	$1486.90	$1110.30	$769.05

Annual Cost Summary

	Cantilever Outlet		Impact Basin	PWD Basin
	Earth Pool	Armor Plate Pool		
Comp. D.S. elev	$44.10	$102.78	$72.82	$50.39
Comp. Head	"	"	$59.84	$28.77



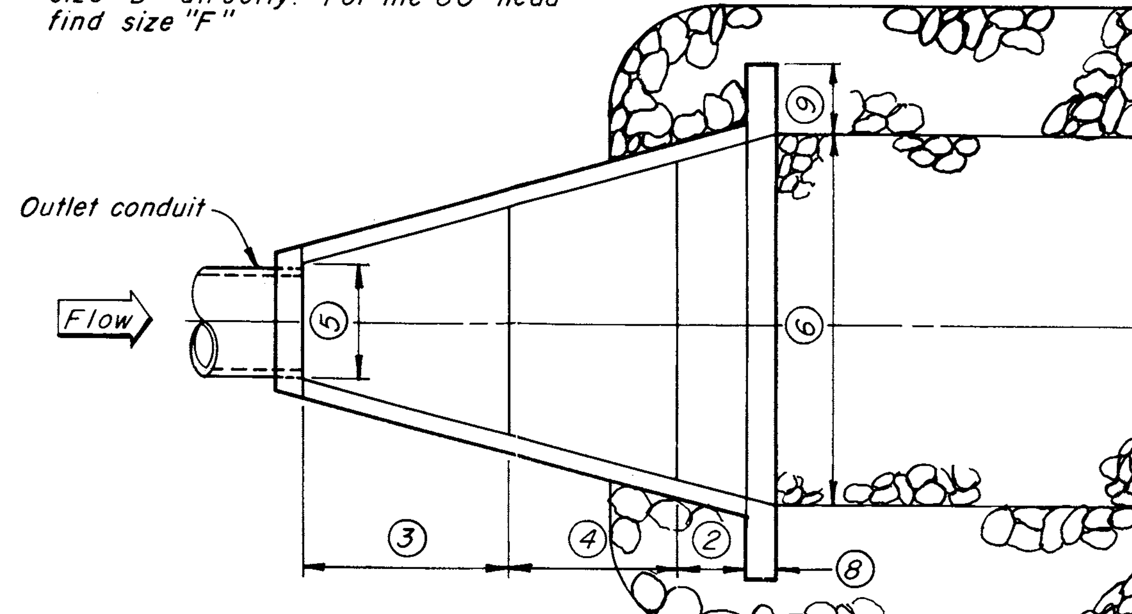
SIZE SELECTION CHART

SIZE / ITEM	STRUCTURE DIMENSIONS A	B	C	D	E	F	G	H
Pipe Dia.	8"	10"-12"	12"-18"	18"-27"	30"-36"	36"-48"	48"-60"	60"-72"
Q-cfs	2-4	5-10	8-24	20-66	58-132	120-280	250-490	450-640
1	1'-0"	1'-0"	1'-6"	2'-3"	3'-0"	4'-0"	5'-0"	6'-0"
2	6"	6"	9"	1'-2"	1'-6"	2'-0"	2'-6"	3'-0"
3	1'-6"	2'-0"	3'-0	4'-6"	6'-0"	8'-0"	10'-0"	12'-0"
4	1'-0"	1'-6"	2'-3"	3'-4"	4'-6"	6'-0"	7'-6"	9'-0"
5	10"	1'-2"	1'-8"	2'-5"	3'-2"	4'-2"	5'-2"	6'-2"
6	2'-8"	3'-6"	5'-4"	8'-3"	11'-0"	14'-4"	17'-10"	21'-4"
7	2'-0"	2'-0"	2'-0"	2'-3"	3'-0"	4'-0"	5'-0"	6'-0"
8	6"	6"	6"	6"	7"	8"	9"	10"
9	2'-0"	2'-6"	3'-6"	4'-6"	6'-0"	8'-0"	10'-0"	12'-0"
Length	3'-6"	4'-6"	6'-6"	9'-6"	12'-7"	16'-8"	20'-9"	24'-10"
Vol. Conc. Cu.Yd.	0.7	1.0	1.9	3.6	7.3	14.7	25.6	40.6
Rein. Steel	54#	76#	148#	274#	447#	742#	2364#	3373#
Std. Dwg. No.	7-E-20463 Suffixed by size letter							

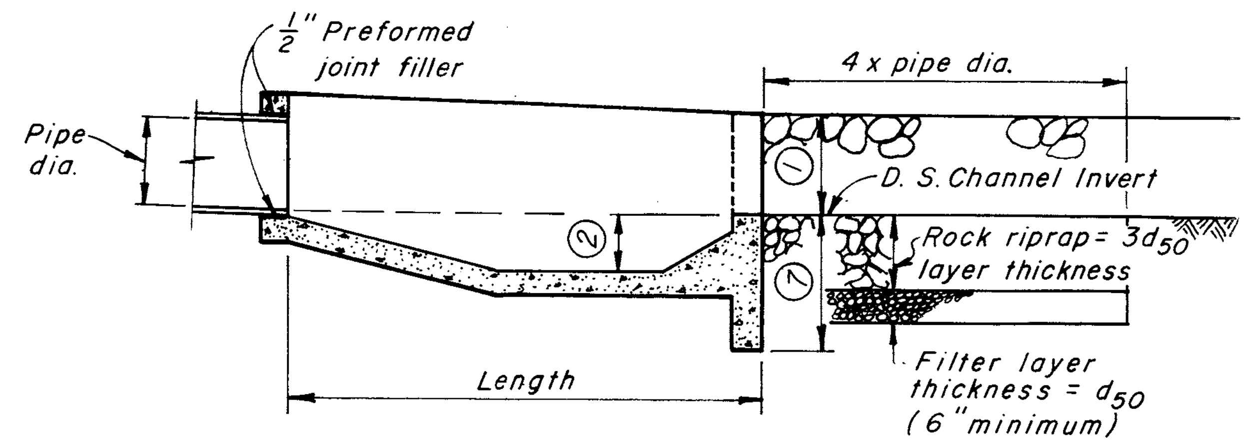
EXAMPLE:

Select structure size for use with a 24" conduit and a
(a) 10' head
(b) 60' head

Enter chart with proper reservoir stage and project a horizontal line to conduit size. For the 10' head find size "D" directly. For the 60' head find size "F"



PLAN



SECTIONAL ELEVATION

Modified Standard Size
Change the following dimensions

Size	5	6
D-1	2'-8"	8'-6"
D-2	3'-2"	9'-2"
E-1	3'-8"	11'-6"
E-2	4'-2"	12'-0"
F-1	4'-8	14'-10"
F-2	5'-2"	15'-4"
G-1	5'-8"	18'-4"
G-2	6'-2"	18'-10

Change quantities according

Refer to Appendix Table J-F1 for refinement in quantities for various conduit types and sizes

For riprap size selection curves for d_{50} see Figure F-3

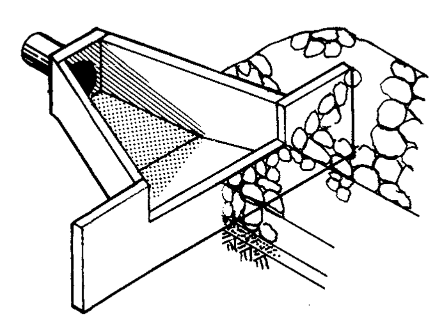
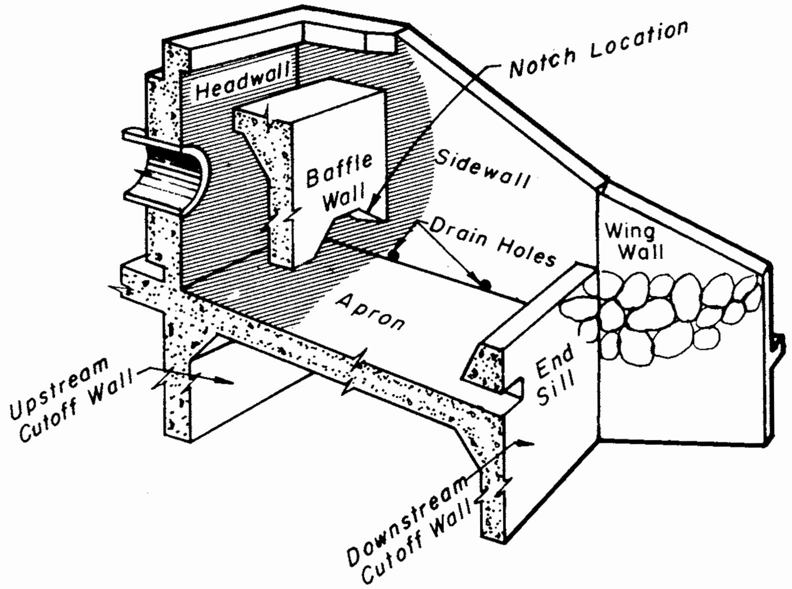


FIGURE F-1
P.W.D. OUTLET STRUCTURE
EWP Unit Portland, Oregon



PERSPECTIVE VIEW

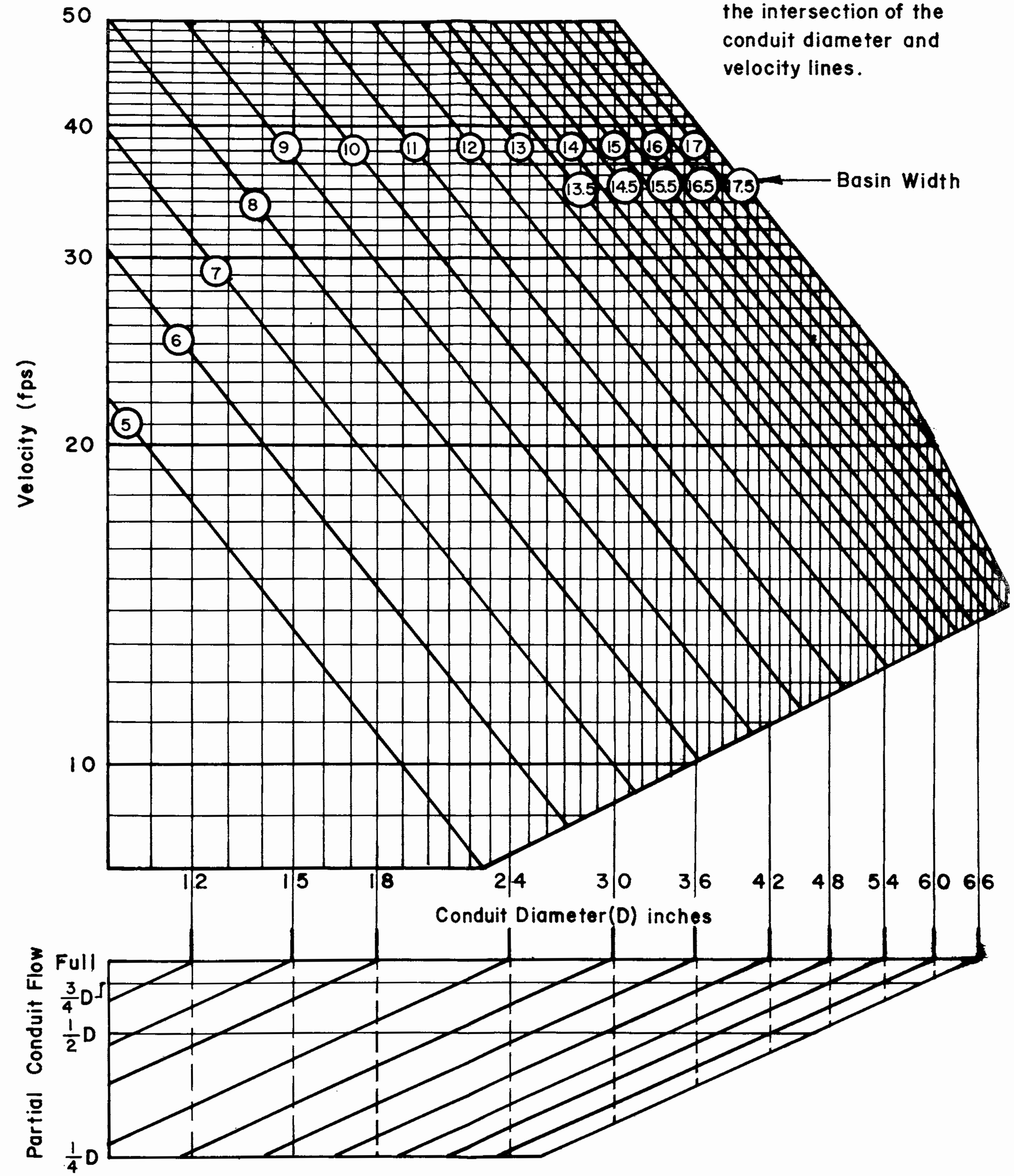
Example:

Conduit dia - - - - - - - 30 inches (full pipe flow)
Velocity - - - - - - - - 20 fps
At intersection find- - - - 10.4 ft basin width
Use standard structure size 11.0 feet

Structure Width feet	Conduit Dia Inches	Quantities *		Std. Drwg. No.
		Concrete-cu.yds.	Reinf. Steel-lbs.	
5	10-18	10.0	1500	ES 4050
6	12-21	12.5	1900	4060
7	15-24	15.0	2200	4070
8	18-30	20.0	2800	4080
9	21-33	23.0	3300	4090
10	24-36	28.0	3900	4100
11	27-42	33.0	4800	4110
12	30-48	38.0	5700	4120
13	33-51	43.5	6700	4130
13.5	33-54	46.5	7300	4135
14	36-57	50.5	7900	4140
14.5	36-57	55.0	8800	4145
15	39-60	58.5	10,000	4150
15.5	39-60	62.0	10,600	4155
16	42-63	65.0	11,000	4160
16.5	42-63	70.0	12,400	4165
17	45-66	73.5	13,300	4170
17.5	45-66	77.0	14,100	4175

* The quantities listed are approximate and vary with the size of the inlet conduit.

Note : The basin width selected shall be that width directly above or to the right of the intersection of the conduit diameter and velocity lines.

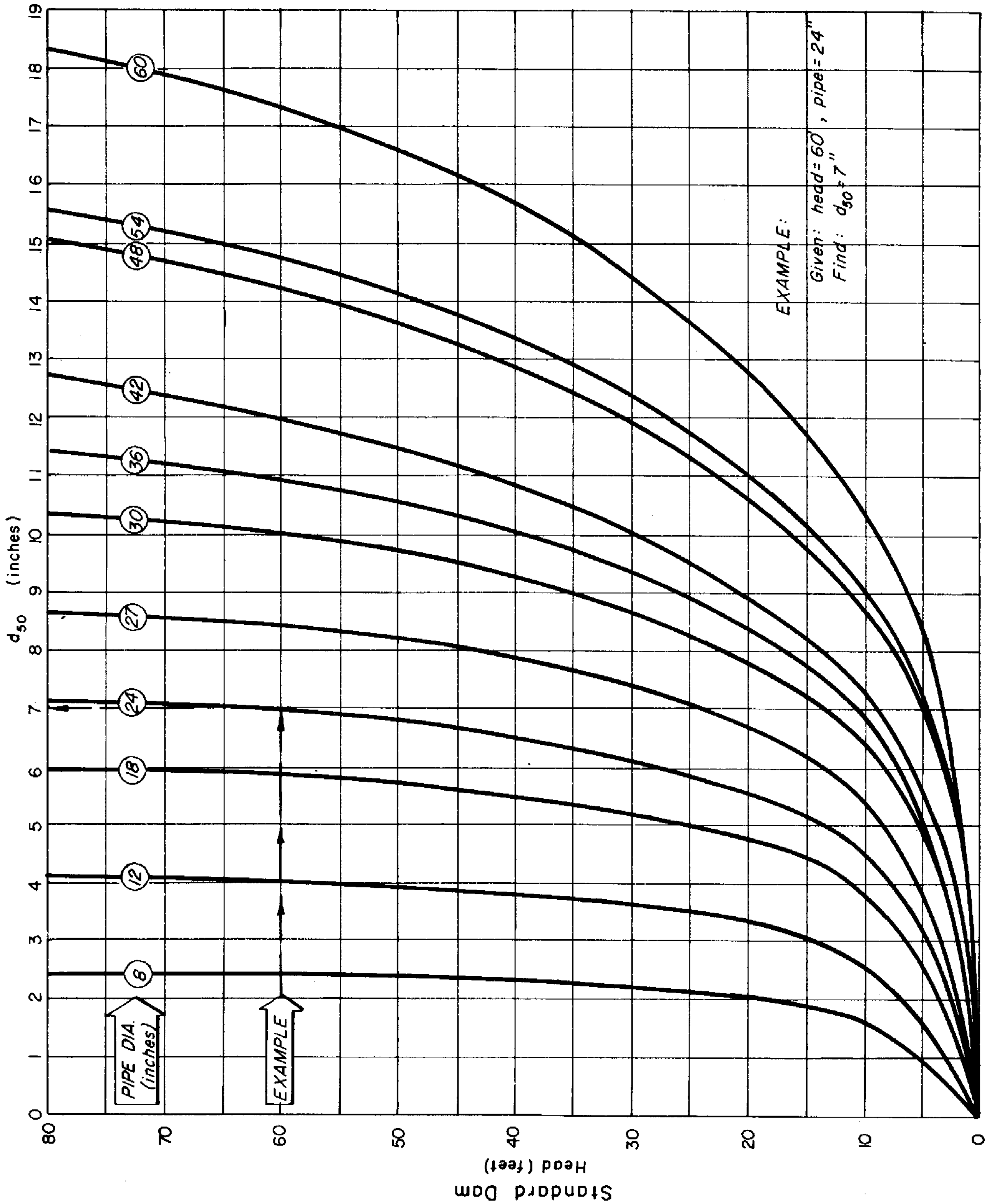


SIZE SELECTION CHART

PRELIMINARY

FIGURE F-2
IMPACT BASIN
OUTLET STRUCTURE
EWP Unit Portland, Oregon

Revised 6-70   Reference: USDI Report # HYD-572



Equation analysis for d_{50}

$$d_{50} = \left[\frac{A_p^2 H}{b^2 \left[2 + (5.2H + 28) k_p \right]} \right]^{\frac{1}{3}} \quad (5.96)$$

A_p = *Area of the pipe* (ft.^{2}) $\quad$ b = *bottom width* (ft.)

H = *Head* (ft.) $\quad$ k_p = *Head loss coefficient for pipe*

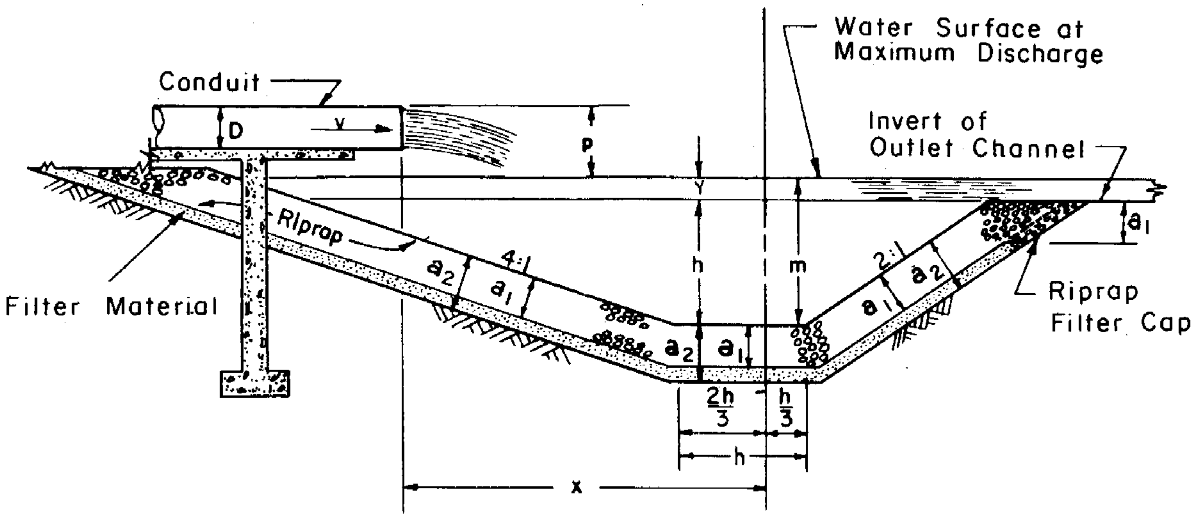
Riprap layer thickness = $3d_{50}$

Filter layer thickness = d_{50}

FIGURE F-3

RIPRAP SIZE SELECTION CURVES (d_{50})

EWP Unit Portland, Oregon



Stilling Basin – Definition Sketch

NOMENCLATURE

a ≡ thickness of riprap or total thickness of riprap and filter material, ft

a_1 ≡ thickness of riprap, ft

a_2 ≡ total thickness of riprap and filter material, ft

d ≡ size of riprap of which 50 percent by weight is smaller, ft

D ≡ inside diameter of conduit, ft

h ≡ depth of stilling basin below invert of outlet channel, ft

m ≡ depth of water in the stilling basin at the maximum conduit discharge, ft

p ≡ vertical distance from the inside crown of the conduit to the water surface in the stilling basin at the maximum conduit discharge, ft

v ≡ mean velocity in the conduit for full pipe flow at maximum discharge, ft/sec

V_a ≡ volume between a horizontal plane at the invert of the outlet channel and a surface at a thickness = a below the exposed riprap surface, cu yds

V_{a_1} ≡ volume of riprap below a horizontal plane at the invert of the outlet channel exclusive of the volume in the Riprap Filter Cap, cu yds
= $V_{a=a_1} - V_{a=o}$

V_{a_2} ≡ volume of filter material below a horizontal plane at the invert of the outlet channel including the volume in the Riprap Filter Cap, cu yds
= $V_{a=a_2} - V_{a=a_1}$

V_{rfc} ≡ volume in the Riprap Filter Cap below a horizontal plane at the invert of the outlet channel, cu yds

x ≡ horizontal distance from the outlet end of the conduit to the center of the stilling basin, ft

EQUATIONS

For determining the depth of the stilling basin,

$$\frac{h}{D^{1/3}} = \left[0.148\ \frac{Q}{D\ d^{1/2}} - 1.82(d)\right]^{2/3} \quad \text{(See sheet 2)}$$

For determining the position of the stilling basin, assuming the conduit is horizontal at the outlet,

$$\frac{x}{\sqrt{p}} = \sqrt{\frac{v^2}{2g}}\left[\sqrt{1 + \frac{m}{p}} + 1 + \frac{m}{2p}\right] \quad \text{(See sheet 3)}$$

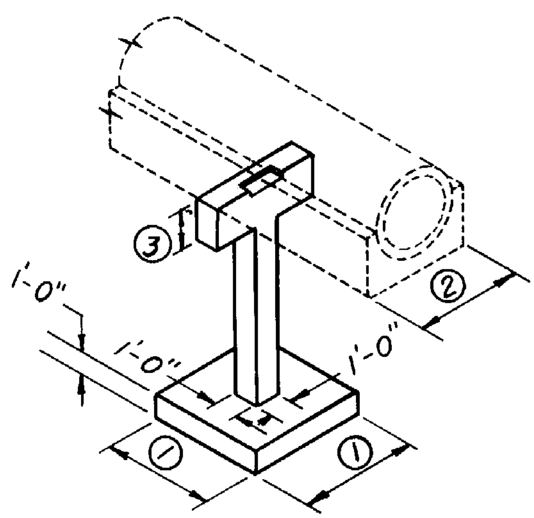
For determining the volumes in the stilling basin,

$$V_a = 2\pi(1.167h + 1.06a)^3 - 0.029(h + 0.36a)^3$$

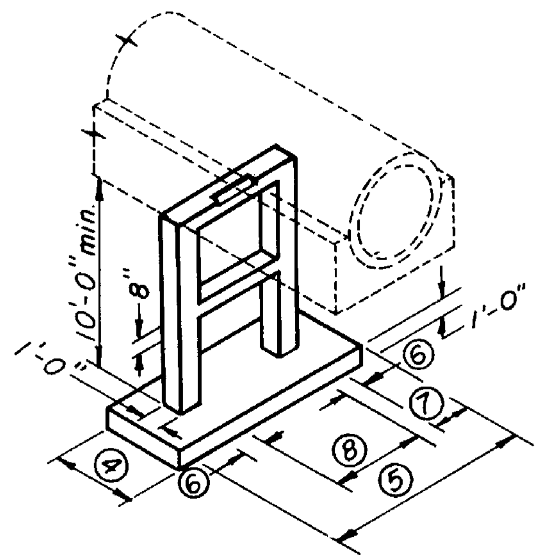
REFERENCE
SCS Design Note No. 6

FIGURE F-4
CANTILEVER OUTLET PLUNGE POOL
EWP Unit Portland, Oregon

CONDUIT SIZE / ITEM	BENT DIMENSIONS										
	12"	15"	18"	21"	24"	30"	36"	42"	48"	54"	60"
1	3'-0"	3'-0"	3'-0"	3'-6"	3'-6"	4'-6"	5'-0"				
2	2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	4'-1"	4'-8"				
3	1'-0"	1'-0"	1'-3"	1'-6"	1'-6"	1'-6"	2'-0"				
4								4'-0"	4'-0"	4'-6"	4'-6"
5								7'-3"	8'-6"	9'-0"	11'-0"
6								1'-0"	1'-0"	1'-0"	1'-2"
7								1'-0"	1'-4"	1'-3½"	2'-0"
8								3'-3"	3'-10"	4'-5"	4'-8"
VOL. CONC. CY.	0.76	0.77	0.77	0.95	0.96	1.29	1.57	1.90	2.10	2.35	2.81
REIN. STEEL	114#	116#	116#	142#	143#	188#	205#	207#	331#	355#	438#
STD. DWG. NO.					ES 105			ES 106			



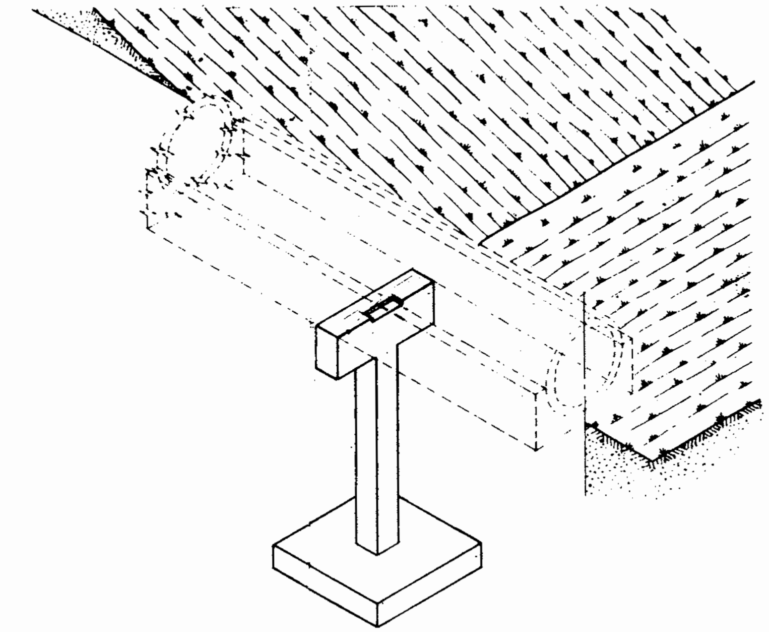
Note:
For conduit size 12" to 36"



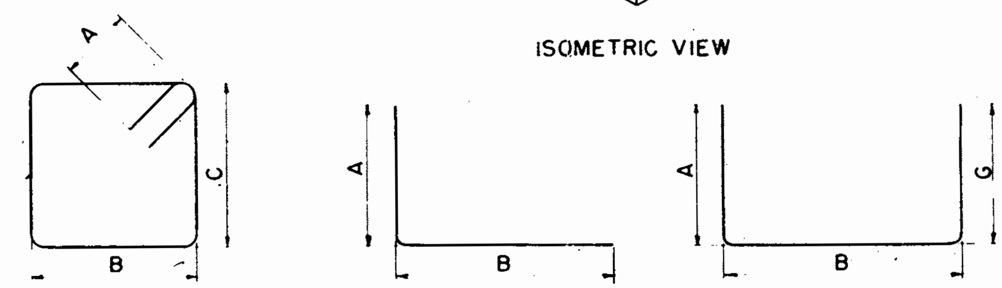
Note:
For conduit size 42" to 60"

FIGURE F-5
CANTILEVER BENT SELECTION CHART
EWP Unit Portland, Oregon

PIPE DIA.	W	R	X	MARK	SIZE	SPACING	d	e	f	g	QUAN.	LENGTH	TYPE	A	G	B	C	TOTAL FT.
24"	3-6	1-6	3-6	F1	4	1-0	0-3				4	3-0	St.					12-0
				F2	4	1-0		0-3			4	3-0	St.					12-0
				F3	4	1-0			0-3		4	3-0	St.					12-0
				F4	4	1-0				0-3	4	3-0	St.					12-0
				F5	6						2	3-0	2	2-0		1-0		6-0
				C6	6						4	9-10	St.					39-4
				C7	3						15	3-2	T1	0-4		0-7½	0-7½	47-6
				T8	4						2	4-5	2	0-9	0-9	2-11		8-10
				T9	6						2	5-1	2	1-0	1-0	3-1		10-2
30"	4-6	1-6	4-1	F1	5	1-0	0-3				5	4-0	St.					20-0
				F2	5	1-0		0-3			5	4-0	St.					20-0
				F3	4	1-0			0-3		5	4-0	St.					20-0
				F4	4	1-0				0-3	5	4-0	St.					20-0
				F5	6						2	3-0	2	2-0		1-0		6-0
				C6	6						4	9-10	St.					39-4
				C7	3						15	3-2	T1	0-4		0-7½	0-7½	47-6
				T8	4						2	5-0	2	0-9	0-9	3-6		10-0
				T9	7						2	5-8	2	1-0	1-0	3-8		11-4
36"	5-0	2-0	4-8	F1	5	1-0	0-6				5	4-6	St.					22-6
				F2	5	1-0		0-6			5	4-6	St.					22-6
				F3	4	1-0			0-6		5	4-6	St.					22-6
				F4	4	1-0				0-6	5	4-6	St.					22-6
				F5	6						2	3-0	2	2-0		1-0		6-0
				C6	6						4	9-10	St.					39-4
				C7	3						15	3-2	T1	0-4		0-7½	0-7½	47-6
				T8	4						2	6-7	2	1-3	1-3	4-1		13-2
				T9	7						2	7-3	2	1-6	1-6	4-3		14-6

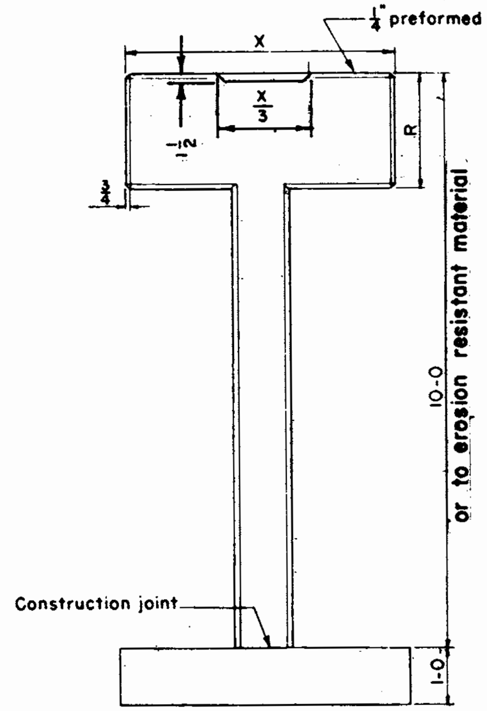


ISOMETRIC VIEW

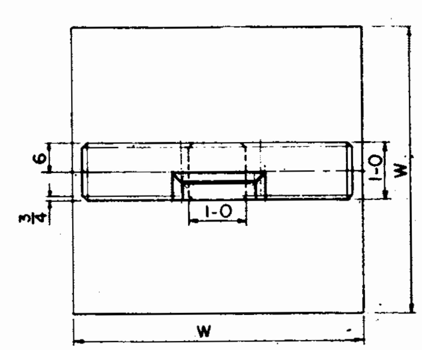


The bar schedule is listed in the approximate order of placement. Bars F1 through F5 are contained in the first pour. All reinforcing steel is round. St. means straight.

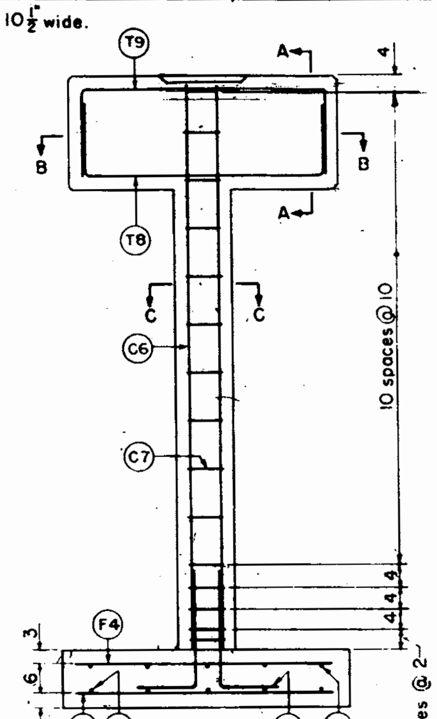
BAR TYPE DETAILS



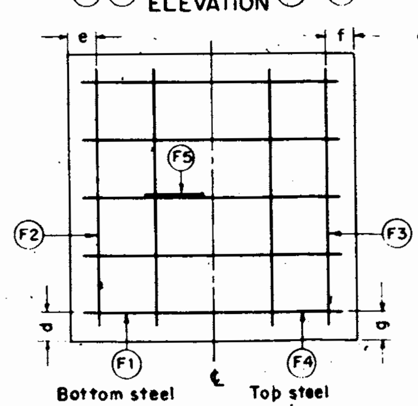
ELEVATION



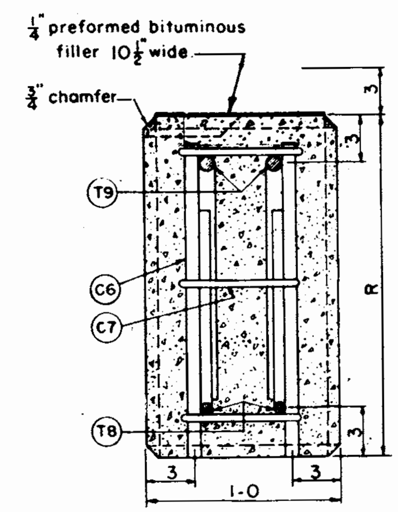
PLAN



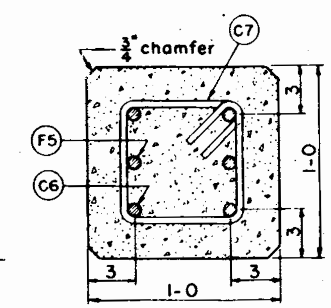
ELEVATION



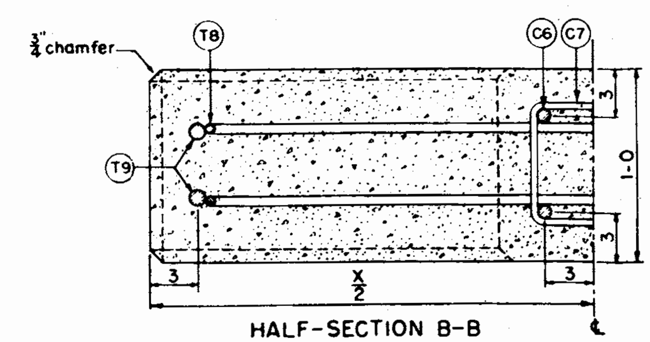
PLAN-FOOTING



SECTION A-A



SECTION C-C



HALF-SECTION B-B

QUANTITIES

PIPE DIAMETER	REINFORCED CONCRETE	REINFORCING STEEL	PREFORMED BITUMINOUS FILLER
24 in.	0.96 cu. yds.	143.03 lbs.	3.0 sq. ft.
30 in.	1.29 cu. yds.	188.08 lbs.	3.5 sq. ft.
36 in.	1.57 cu. yds.	205.27 lbs.	4.0 sq. ft.

NOTES

1. Class "B" concrete, $f'_c = 3{,}000$ psi. $f_s = 20{,}000$ psi
2. All exposed edges will have ¾ inch chamfer
3. All reference to pipe diameter is the inside diameter of the outlet pipe.
4. The bar mark numbers indicate the respective bar locations.
5. Quantities include column and footing
6. All steel placement dimensions are to center of bars.

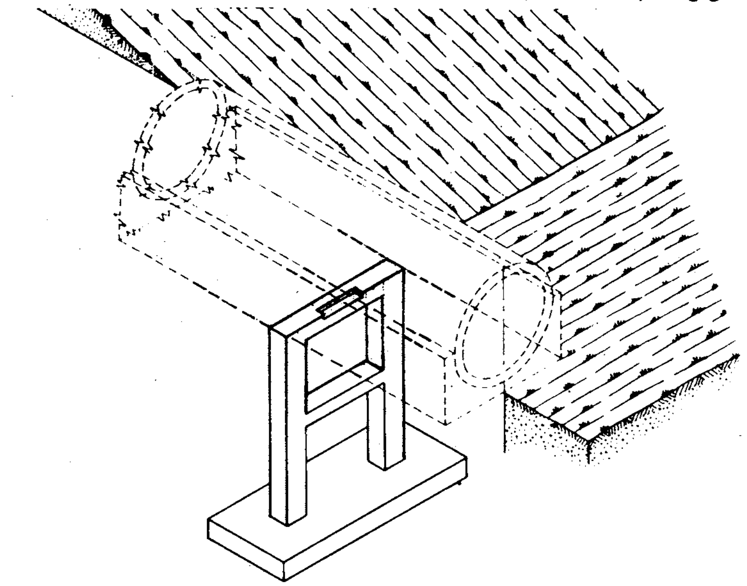
REFERENCE:
ES 105

FIGURE F-6

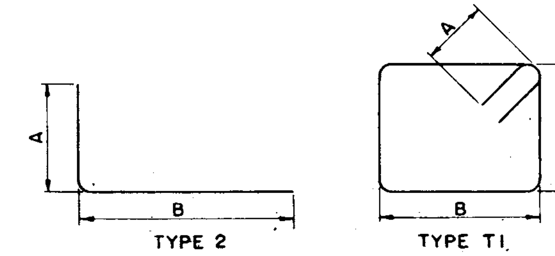
CANTILEVER OUTLET BENT

EWP Unit Portland, Oregon

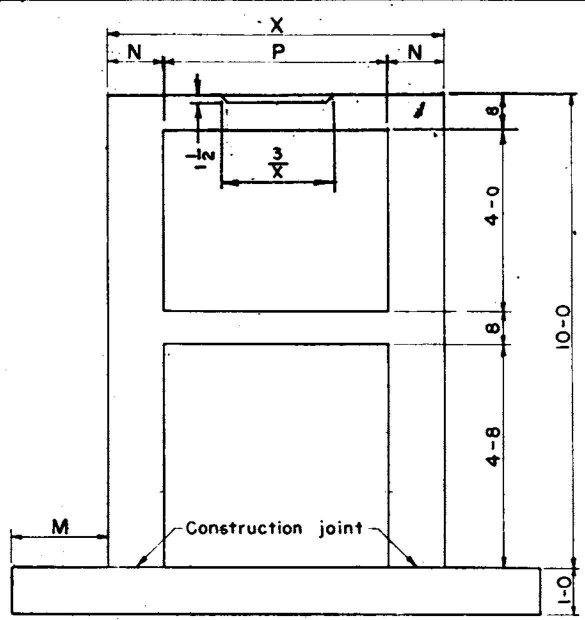
PIPE DIA.	W	L	M	N	P	X	MARK	SIZE	SPACING	d	e	f	g	QUAN.	LENGTH	TYPE	A	B	C	TOTAL FT.
42"	4-0	7-3	1-0	1-0	3-3	5-3	F1	4	1-2	0-3	0-3¼	0-3¼	0-4	4	6-9	St.				27-0
							F2	4	0-11½					8	3-6	St.				28-0
							F3	4	0-11½					8	3-6	St.				28-0
							F4	4	0-10					5	6-9	St.				33-9
							F5	6						4	2-6	2	1-6	1-0		10-0
							C6	6						8	9-10	St.				78-8
							C7	3						26	3-2	T1	0-4	0-7½	0-7½	82-4
							C8	4	0-6					8	4-6	2	1-0	3-6		36-0
							C9	4	0-6					2	4-9	St.				9-6
48"	4-0	8-6	1-4	1-0	3-10	5-10	F1	4	0-10	0-4	0-3	0-3	0-4	5	8-0	St.				40-0
							F2	4	1-0					9	3-6	St.				31-6
							F3	4	1-0					9	3-6	St.				31-6
							F4	4	0-10					5	8-0	St.				40-0
							F5	6						4	2-6	2	1-6	1-0		10-0
							C6	7						8	9-10	St.				78-8
							C7	3						26	3-4	T1	0-4	0-8	0-8	86-8
							C8	4	0-6					8	5-0	2	1-0	4-0		40-0
							C9	4	0-6					2	5-6	St.				11-0
54"	4-6	9-0	1-3½	1-0	4-5	6-5	F1	4	1-0	0-3	0-4½	0-6	0-3	5	8-6	St.				42-6
							F2	4	0-11					10	4-0	St.				40-0
							F3	4	1-0					9	4-0	St.				36-0
							F4	4	0-8					7	8-6	St.				59-6
							F5	6						4	2-6	2	1-6	1-0		10-0
							C6	7						8	9-10	St.				78-8
							C7	3	1-0					26	3-4	T1	0-4	0-8	0-8	86-8
							C8	4	0-6					8	5-3	2	1-0	4-3		42-0
							C9	4	0-6					2	6-0	St.				12-0
60"	4-6	11-0	2-0	1-2	4-8	7-0	F1	4	0-8	0-3	0-3	0-6	0-3	7	10-6	St.				73-6
							F2	4	0-10½					13	4-0	St.				52-0
							F3	4	1-0					11	4-0	St.				44-0
							F4	4	1-0					5	10-6	St.				52-6
							F5	6						4	2-6	2	1-6	1-0		10-0
							C6	8						8	9-10	St.				78-8
							C7	3						26	3-8	T1	0-4	0-10	0-8	95-4
							C8	4	0-6					8	5-6	2	1-0	4-6		44-0
							C9	4	0-6					2	6-8	St.				13-4



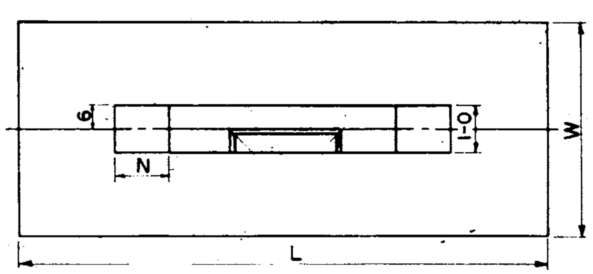
ISOMETRIC VIEW



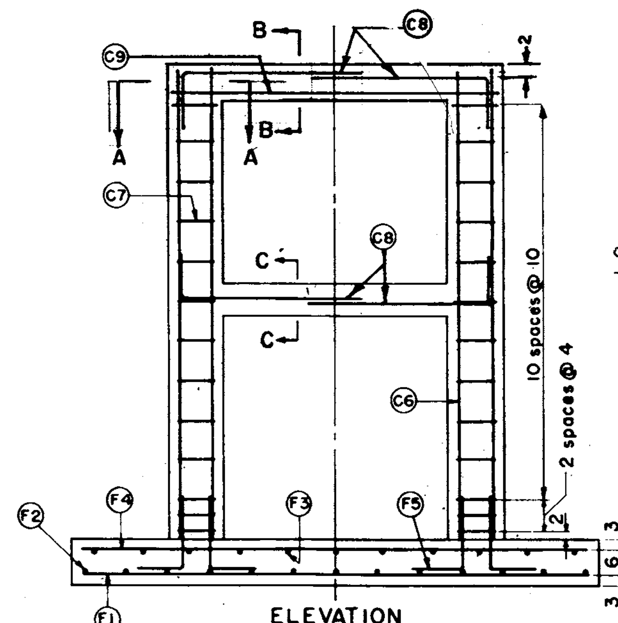
BAR TYPE DETAILS



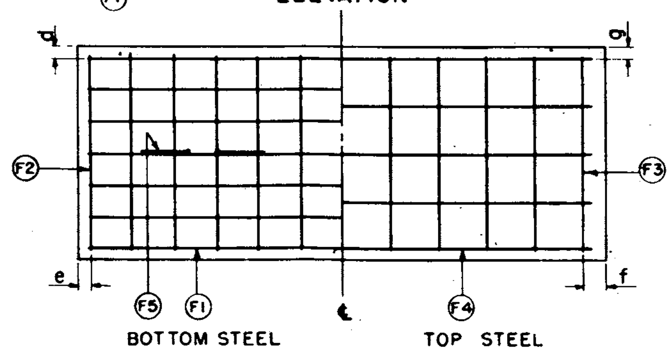
ELEVATION



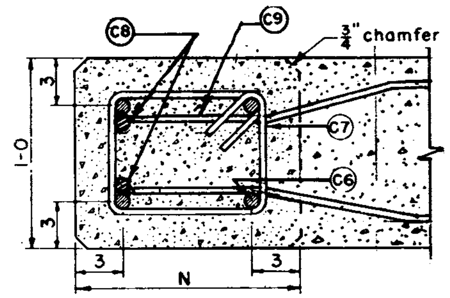
PLAN



ELEVATION



PLAN-FOOTING

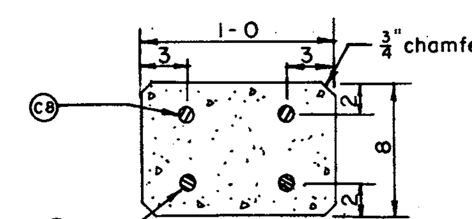


SECTION A-A

The bar schedule is listed in the approximate order of placement. Bars F1 through F5 are contained in the first pour. All reinforcing steel is round. St. is an abbreviation for straight.

QUANTITIES

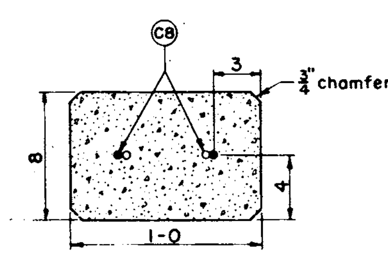
PIPE DIAMETER	REINF. CONCRETE	REINF. STEEL
42 in.	1.98 cu. yds.	279.24 lbs.
48 in.	2.17 cu. yds.	345.72 lbs.
54 in.	2.46 cu. yds.	371.16 lbs.
60 in.	2.93 cu. yds.	456.56 lbs.



SECTION B-B

NOTES

1. Class "B" concrete. $f'_c = 3{,}000$ psi. $f_s = 20{,}000$ psi.
2. All exposed edges will have ¾ inch chamfer
3. All reference to pipe diameter is the inside diameter of the outlet pipe.
4. The bar mark numbers indicate the respective bar locations.
5. Quantities include columns, tie beam, and footing
6. All steel placement dimensions are to center of bars.

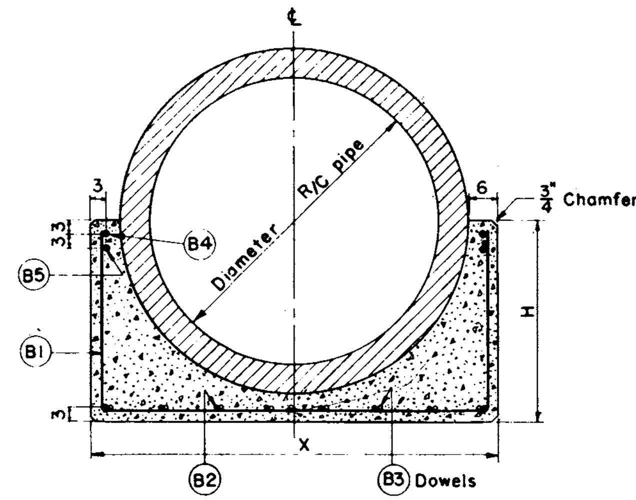


SECTION C-C

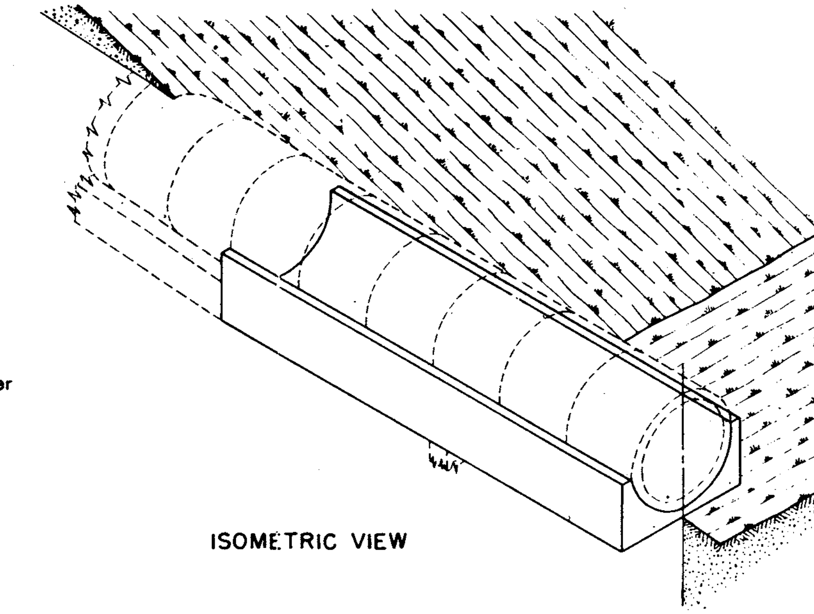
REFERENCE:
ES 106

FIGURE F-7
CANTILEVER OUTLET BENT
EWP Unit Portland, Oregon

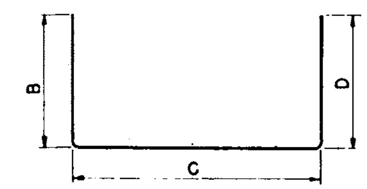
PIPE DIA.	X	H	MARK	SIZE	SPACING	QUAN.	LENGTH	TYPE	B	C	D	TOTAL FT.
24"	3-6	1-9	B1	4	1-0	24	5-11	S10	1-5	3-1½	1-5	142-0
			B2	4	1-0	4	23-6	St.				94-0
			B3	4	1-0	4	5-0	St.				20-0
			B4	9		2	23-6	St.				47-0
30"	4-1	2-0½	B1	4	1-0	24	7-1	S10	1-8½	3-8½	1-8½	170-0
			B2	4	0-11	5	23-6	St.				117-6
			B3	4	0-11	5	5-0	St.				25-0
			B4	7		2	23-6	St.				47-0
			B5	7		2	23-6	St.				47-0
36"	4-8	2-4	B1	4	1-0	24	8-3	S10	2-0	4-3½	2-0	198-0
			B2	4	0-10	6	23-6	St.				141-0
			B3	4	0-10	6	5-0	St.				30-0
			B4	8		2	23-6	St.				47-0
			B5	8		2	23-6	St.				47-0
42"	5-3	2-7½	B1	4	1-0	24	9-5	S10	2-3½	4-10½	2-3½	226-0
			B2	4	0-11½	6	23-6	St.				141-0
			B3	4	0-11½	6	5-0	St.				30-0
			B4	8		2	23-6	St.				47-0
			B5	8		2	23-6	St.				47-0
48"	5-10	2-11	B1	4	1-0	24	10-7	S10	2-7	5-5½	2-7	254-0
			B2	4	0-10½	7	23-6	St.				164-6
			B3	4	0-10½	7	5-0	St.				35-0
			B4	8		2	23-6	St.				47-0
			B5	8		2	23-6	St.				47-0
54"	6-5	3-2½	B1	4	1-0	24	11-9	S10	2-10½	6-0½	2-10½	282-0
			B2	4	0-11½	7	23-6	St.				164-6
			B3	4	0-11½	7	5-0	St.				35-0
			B4	9		2	23-6	St.				47-0
			B5	9		2	23-6	St.				47-0
60"	7-0	3-6	B1	4	0-9½	30	12-11	S10	3-2	6-7½	3-2	387-6
			B2	4	0-11	8	23-6	St.				188-0
			B3	4	0-11	8	5-0	St.				40-0
			B4	9		2	23-6	St.				47-0
			B5	9		2	23-6	St.				47-0



SECTION A–A



ISOMETRIC VIEW



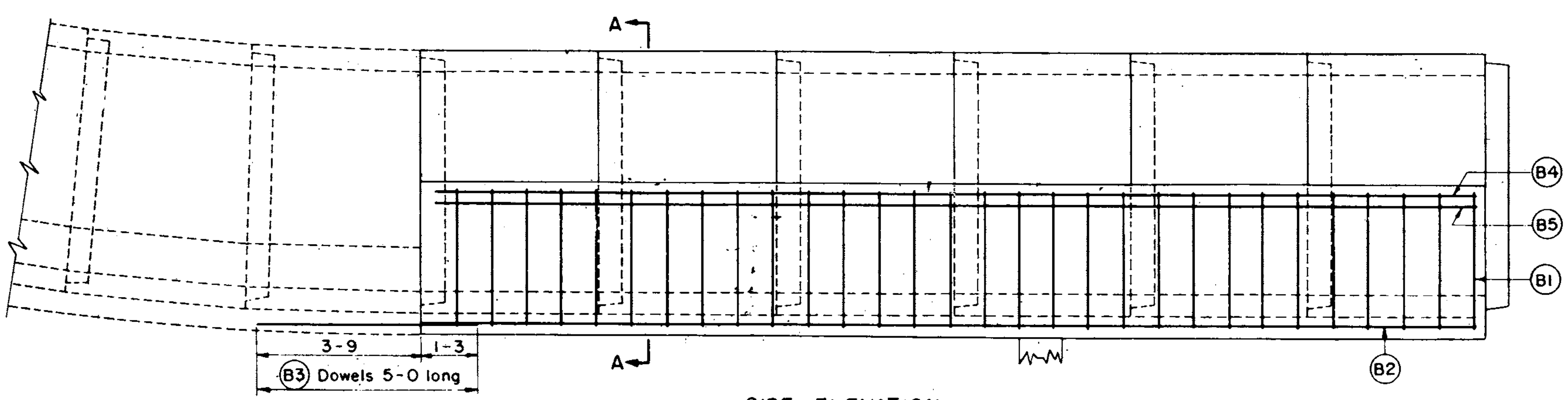
TYPE S10

BAR TYPE DETAIL

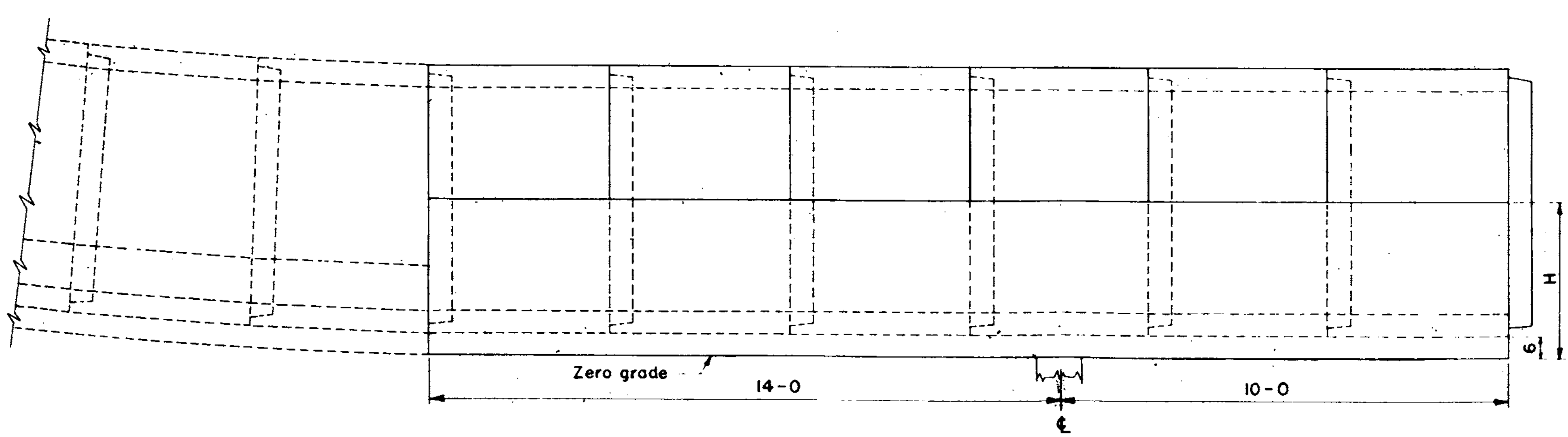
The bar schedule is listed in the approximate order of placement. All reinforcing steel is round. St. is an abbreviation for straight

QUANTITIES

PIPE DIAMETER	REINFORCED CONCRETE	REINFORCING STEEL
24 in.	3.26 cu. yds.	330.81 lbs.
30 in.	4.09 cu. yds.	400.89 lbs.
36 in.	4.99 cu. yds.	497.47 lbs.
42 in.	5.94 cu. yds.	516.18 lbs.
48 in.	6.97 cu. yds.	553.92 lbs.
54 in.	8.06 cu. yds.	641.24 lbs.
60 in.	9.21 cu. yds.	730.75 lbs.



SIDE ELEVATION



SIDE ELEVATION

NOTES

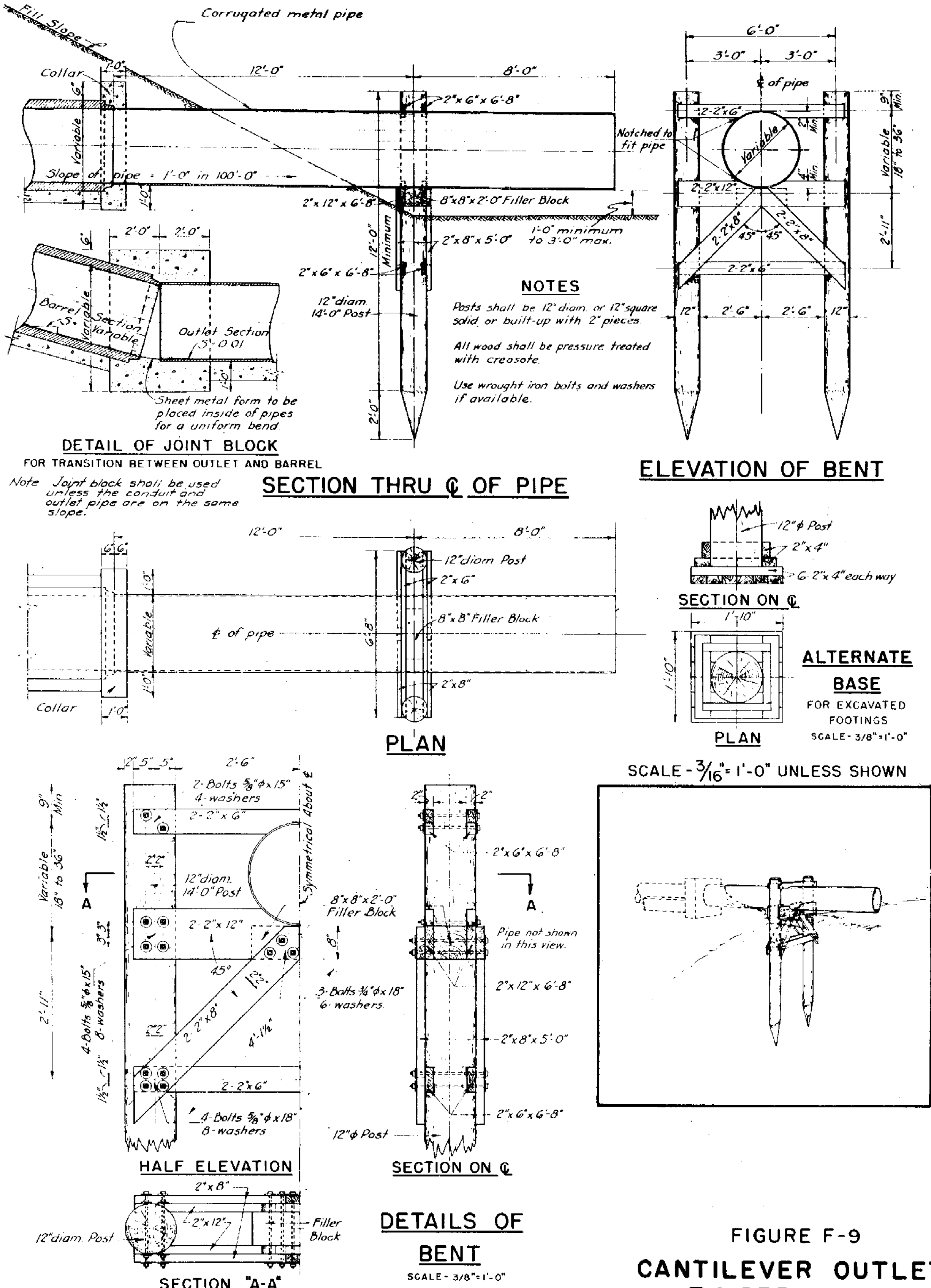
1. Class "B" concrete, $f'_c = 3{,}000$ psi $f_s = 20{,}000$ psi
2. All exposed edges will have ¾ inch chamfer
3. All reference to pipe diameter is the inside diameter of the outlet pipe.
4. The outlet pipe will be standard strengh R/C pipe with an an over-all length of 24 feet.
5. Quantities include the beam only
6. The bar mark numbers are the respective bar locations
7. All steel placement dimensions are to center of bars

FIGURE F-8

CANTILEVER OUTLET DETAIL

EWP Unit Portland, Oregon

REFERENCE:
ES 107



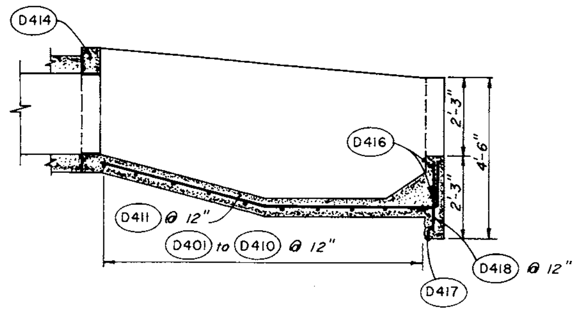
REFERENCE : 3-L-12524

Revised 5-22-53

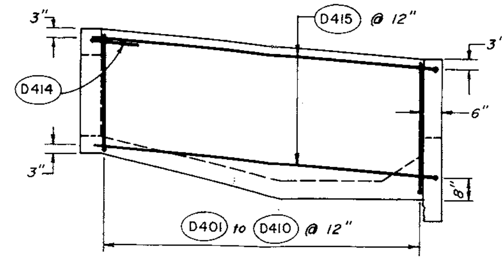
FIGURE F-9

CANTILEVER OUTLET TIMBER BENT

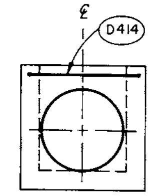
EWP Unit Portland, Oregon



SECTIONAL ELEVATION

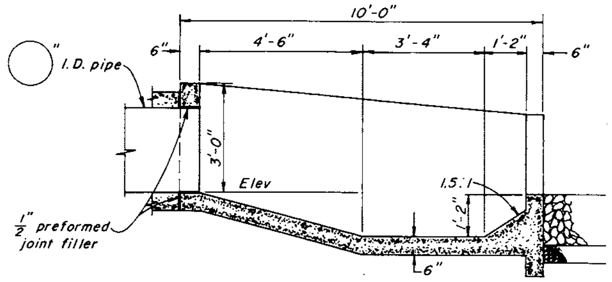


SIDEWALL ELEVATION

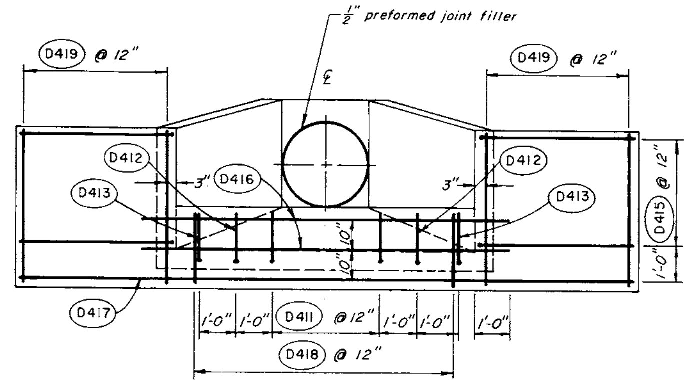


HEADWALL ELEVATION

Location	Size	Mark	Quan.	Length	Type	A	B	G	Total Length
P.W.D. BASIN									
Slab	4	D401	2	5'-3"	2	2'-3"	3'-0"		10'-6"
"	4	D402	2	5'-6"	2	2'-3"	3'-3"		11'-0"
"	4	D403	2	6'-0"	2	2'-6"	3'-6"		12'-0"
"	4	D404	2	6'-6"	2	3'-0"	3'-6"		13'-0"
"	4	D405	2	7'-0"	2	3'-3"	3'-9"		14'-0"
"	4	D406	2	7'-3"	2	3'-6"	3'-9"		14'-6"
"	4	D407	2	7'-6"	2	3'-9"	3'-9"		15'-0"
"	4	D408	2	7'-9"	2	4'-0"	3'-9"		15'-6"
"	4	D409	2	7'-9"	2	4'-3"	3'-6"		15'-6"
"	4	D410	2	8'-3"	2	4'-9"	3'-6"		16'-6"
"	4	D411	4	10'-6"	SPA	4'-6"	4'-9"	1'-3"	42-0"
"	4	D412	2	7'-3"	SPA	1'-3"	4'-9"	1'-3"	14'-6"
"	4	D413	2	4'-0"	2	2'-9"	1'-3		8'-0"
Sidewall	4	D414	1	5'-3"	SPB	1'-3"	2'-9"	1'-3"	5'-3"
"	4	D415	8	14'-0"	SPB	4' 0	10'-0"		112'-0"
Cutoff wall	4	D416	2	10'-3"	Str				20'-6"
"	4	D417	1	16'-9"	Str				16'-9"
"	4	D418	8	1'-9"	Str				14'-0"
"	4	D419	10	4'-0"	Str				40'-0"

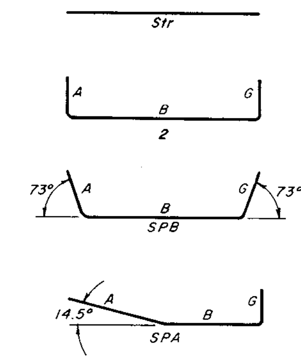


SECTIONAL ELEVATION

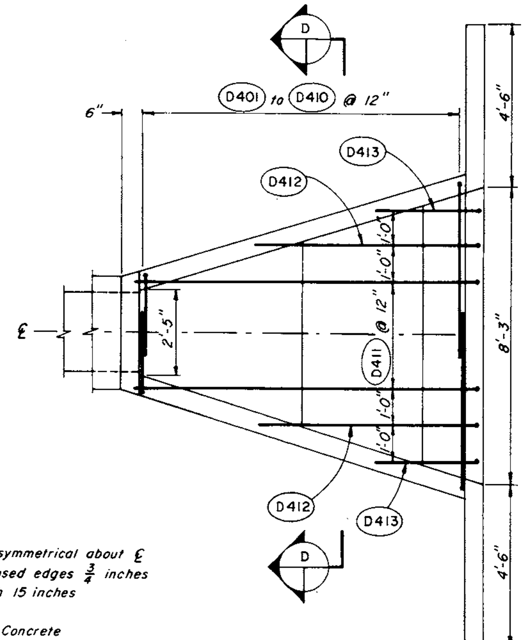


WINGWALL ELEVATION

TABLE OF QUANTITIES				
	I.D. of pipe In.	Type of pipe ASTM 76 & AWWA C 302 Cu Yds	AWWA C 300 & C 301 Cu Yds	Steel & C.M.P. Cu Yds
Concrete	18	3.67	3.67	3.70
	20		3.65	3.68
	21	3.65		3.67
	24	3.63	3.63	3.66
	27	3.61		3.64
Reinf Steel	274 lbs			



BAR TYPES



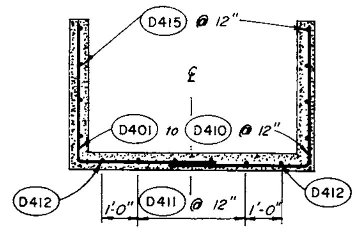
Notes:

Structure is symmetrical about ℄
Chamfer exposed edges 3/4 inches
Splice length 15 inches

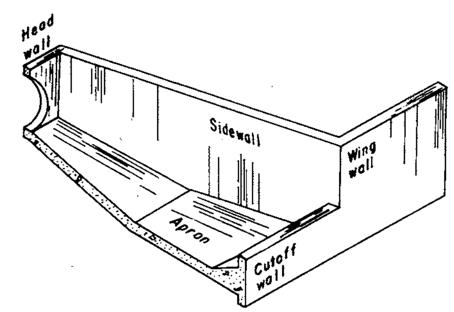
Class 3000 Concrete
f_s = 20,000 psi
f'_c = 3000 psi
f_c = 1350 psi

PLAN

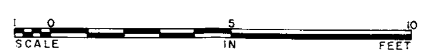
Refer to Table J-F1 for refinement in concrete volume



SECTION D



HALF ISOMETRIC VIEW



P. W.D. BASIN SIZE D
PORTLAND, OREGON E & WP UNIT

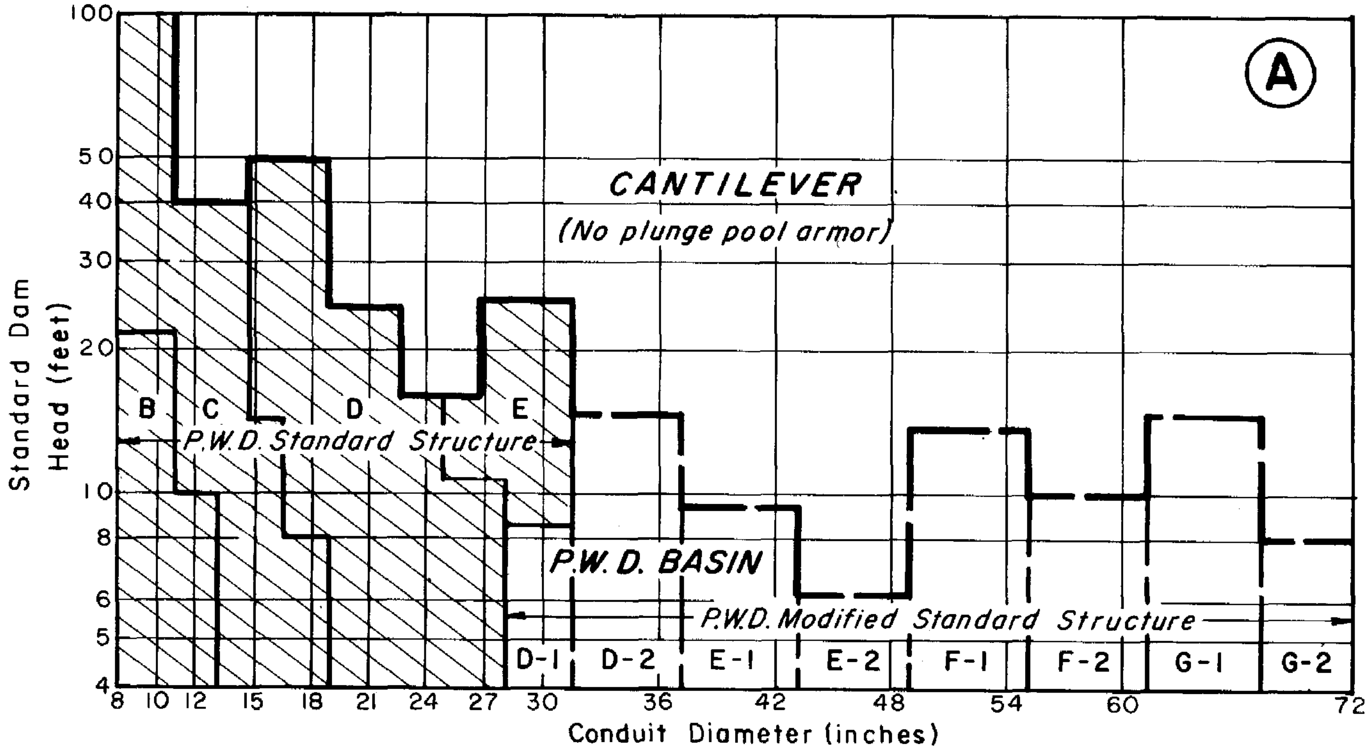
TABLE OF QUANTITIES	
Concrete	cu yd
Reinforcing steel	274 lbs

FIGURE F-10
P.W.D. BASIN
EWP Unit Portland, Oregon

Desig
Drawn
Traced
Checked
Title
Sheet No of
Drawing No.

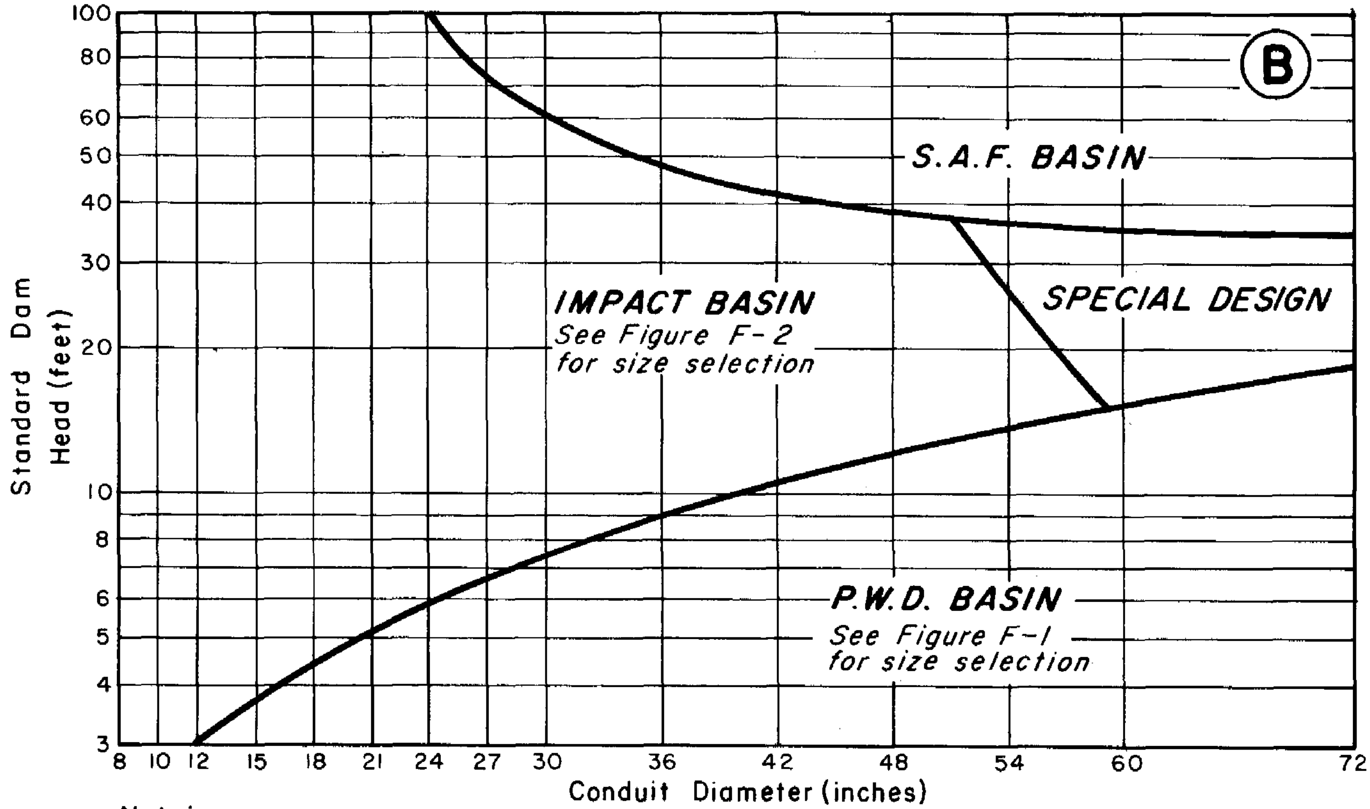
7-E-20463-D

CONDITION 1 Rock riprap not required



CONDITION 2 Rock riprap required

When unit cost ratio of R/C to rock riprap is less than 13 use Chart B. If the ratio is greater than 13 compare costs of the structure selected from Chart B with that of a cantilever and armored plunge pool.



Note:
Charts A and B apply for full conduit flow.

FIGURE F-11

OUTLET STRUCTURE SELECTION CHARTS

EWP Unit Portland, Oregon